5. SITE 470: OFF GUADALUPE ISLAND[1]

Shipboard Scientific Party[2]

HOLES 470, 470A

Date occupied: 3 November 1978 (470); 4 November 1978 (470A)

Date departed: 4 November 1978 (470); 5 November 1978 (470A)

Position: 28°54.46′N, 117°31.11′W (470, 470A)

Water depth (sea level; corrected m, echo-sounding): 3549 (470, 470A)

Bottom felt (m, drill pipe): 3554.5 (470, 470A)

Penetration (m): 168 (470); 215.5 (470A)

Number of cores: 18 (470); 13 (470A)

Total length of cored section (m): 168 (470); 101.5 (470A)

Total core recovered (m): 90 (470); 48.2 (470A)

Core recovery (%): 54 (470); 47 (470A)

Oldest sediment cored:
Depth sub-bottom (m): 163 (470); 167 (470A)
Nature: Nannofossil ooze
Chronostratigraphy: Middle Miocene (15.5 m.y.)

Basement:
Depth sub-bottom (m): 163 (470); 167 (470A)
Nature: Pillow basalt

Principal results: Site 470, east of Guadalupe Island, was proposed in order to core continuously the sediment section that had been only partially recovered in 1961 at the Experimental Mohole site, located about 8 km to the north-northeast. Hole 470 was continuously cored to basalt at 163 meters. The hole was respudded to resample critical sediment intervals of poor recovery. Hole 470A was cored continuously from 47.5 to 95 meters and from 161.5 to 167 meters (for an additional paleontologic survey of sediments), then continuously cored in basalt to 215.5 meters. The composite section is described later.

Sediments are Quaternary silty clay to 32 meters, upper Miocene to upper Pliocene nannofossil clay to 68 meters, middle and upper Miocene diatomaceous silty clay, diatomaceous nannofossil clay, and minor ooze to 126 meters, middle Miocene nannofossil ooze and diatomaceous nannofossil ooze to 162 meters, and more compact middle Miocene nannofossil ooze and clayey nannofossil ooze with dolomite increasing downsection to the top of basalt at 167 meters. Uniform sediment velocity is 1.5 km/s, and sediment density is 1.5 g/cm^3, except in basal sediments, where it is 1.75 g/cm^3. Sedimentation rates range from 14 to 16 m/m.y., with hiatuses 3 to 4.4 m.y., 5.8 to 7.4 m.y., and 8.4 to 10 m.y. ago (the upper hiatus is more speculative). The top of the basalt is 4 meters deeper at Hole 470A than at Hole 470. Basalt densities range from 2.62 to 2.93 g/cm^3 and velocities from 4.9 to 6 km/s. There are three basalt sequences: pillow basalt with glassy margins (167 to 183 m), diabase sills or massive flows (183 to 189 m), and pillow basalt to the bottom of the hole. Occasional limestone lenses with middle Miocene coccoliths occur in the basalt.

BACKGROUND AND OBJECTIVES

In the 1950s, the Mohole Project was conceived for the purpose of drilling through the ocean crust to the Mohorovičić discontinuity. The Mohole Project was terminated before completion, but an intermediate experiment was conducted off Guadalupe Island, Mexico, to determine the feasibility of recovering cores of sediment in deep water beyond the reach of piston cores using a conventional offshore drilling vessel. Several holes were drilled at this site in 1961, using the *CUSS 1* (AMSOC Comm., 1961; Riedel et al., 1961). Samples from these holes were sent to members of the scientific community, who subsequently produced reports on engineering properties of sediments (Moore, 1964; Hamilton, 1964), sediment velocities (Hamilton, 1965), bulk densities (Igelman and Hamilton, 1963), and organic geochemistry (Rittenberg et al., 1963). Basalt recovered at the base of the section was studied by Engel and Engel (1961) and K-Ar dated by Krueger (1964). Heat flow was measured by Von Herzen and Maxwell (1964). K-Ar dates on two sediment samples were provided by Dymond (1966). Biostratigraphic studies were done on foraminifers (Parker, 1964; Bandy and Ingle, 1970), calcareous nannoplankton (Martini and Bramlette, 1963; Martini, 1971), silicoflagellates (Martini, 1972), and diatoms (Kanaya, 1971; Schrader, 1974). These biostratigraphic studies, together with those done for DSDP Site 173 off northern California, form much of the foundation for studies of paleoceanography and paleoclimatology of the northeastern Pacific (cf. Ingle, 1973).

The great scientific success of the *CUSS* core holes at the Guadalupe site led to the formation of JOIDES and to the commissioning of the *Glomar Challenger* to carry out a deep-ocean coring program in the oceans of the world. The distribution of samples and publication in various journals became a guide for the present *Initial Reports of the Deep Sea Drilling Project.*

Drilling at the Experimental Mohole Guadalupe site left many questions unanswered. Core recovery was poor above 80 meters, and there was no core material at all in the upper 30 meters. Thus no diatom zones younger than NPD10 were identified; poor nannofossil zonation existed above NN11; and the post-Miocene

[1] *Initial Reports of the Deep Sea Drilling Project*, Volume 63.
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record was virtually unknown (cf. Schrader, 1974). The K-Ar ages of basalt were 15 ± 7 m.y. and 32 ± 10 m.y. (Krueger, 1964)—data that provided more questions than answers. Possibly basement was not reached, and the basalt encountered was actually a sill. Accordingly, it was appropriate to revisit the Guadalupe site 17 years later with better coring technology to complete the stratigraphic record begun in 1961.

Site 470 is one of the more important paleoenvironmental sites of Leg 63 (Fig. 1). Its strategic location beneath the present-day mixing zone between the distal part of the California Current and the eastern equatorial water makes it inherently sensitive to climatic fluctuations. Excursions of the ocean front, both major and minor, are more likely to be recorded here than at higher or lower latitudes. The sedimentary record recovered at the Experimental Mohole site suggests that an almost complete Neogene section may be present, if the sill complex that the Mohole bottomed in could be penetrated. Because of its sensitivity to relatively short phase changes, Site 470 also offers a setting in which we can effectively study the responses of planktonic communities to a highly stressed environment through most of the Neogene. For the same reason, the site is also well suited for the recovery of a biostratigraphic record intermediate between the temperate latitudes and the cooler, higher latitudes. Such a record may also provide us with an insight into the climatically induced time-transgressive nature and duration of certain biochronologic datum levels.

Proposed Site 470 was located at some 3750 meters water depth on the abyssal sea floor west of Baja California (Fig. 2) in a region characterized by north-trending magnetic anomalies midway between Anomalies 5 and 6 (about 15 m.y. in age, according to the geomagnetic time scale of Heirtzler et al. [1968] and also according to the theoretical basement age versus basement depth curve of Sclater et al. [1971]). Figure 2 locates the site with respect to the Experimental Mohole, and Figure 3 illustrates the relatively uniform thickness of pelagic oceanic sediments over an irregular surface of oceanic crust.

The site lies between two prominent west-trending features that are probably fracture zones (cf. Calderon, 1978). On the south is Shirley trough (not shown in Fig. 2), an eastern extension of the Molokai fracture zone. Magnetic anomalies suggest that the Shirley trough separates older crust on the south from younger crust on the north. North of the site is Popcorn ridge, which may also separate older crust on the south from younger crust on the north (see the bathymetric map in Fig. 2). East of the site is the Cedros deep, possibly a fossil trench marking the boundary between the continent and the now-vanished Farallon plate. The Cedros deep terminates on the north at Popcorn ridge. Krause (1965) named the area around the site the Guadalupe Arrugado, or rolling plain. The topographic grain of the Guadalupe Arrugado is north-south, consistent with the magnetic anomalies.

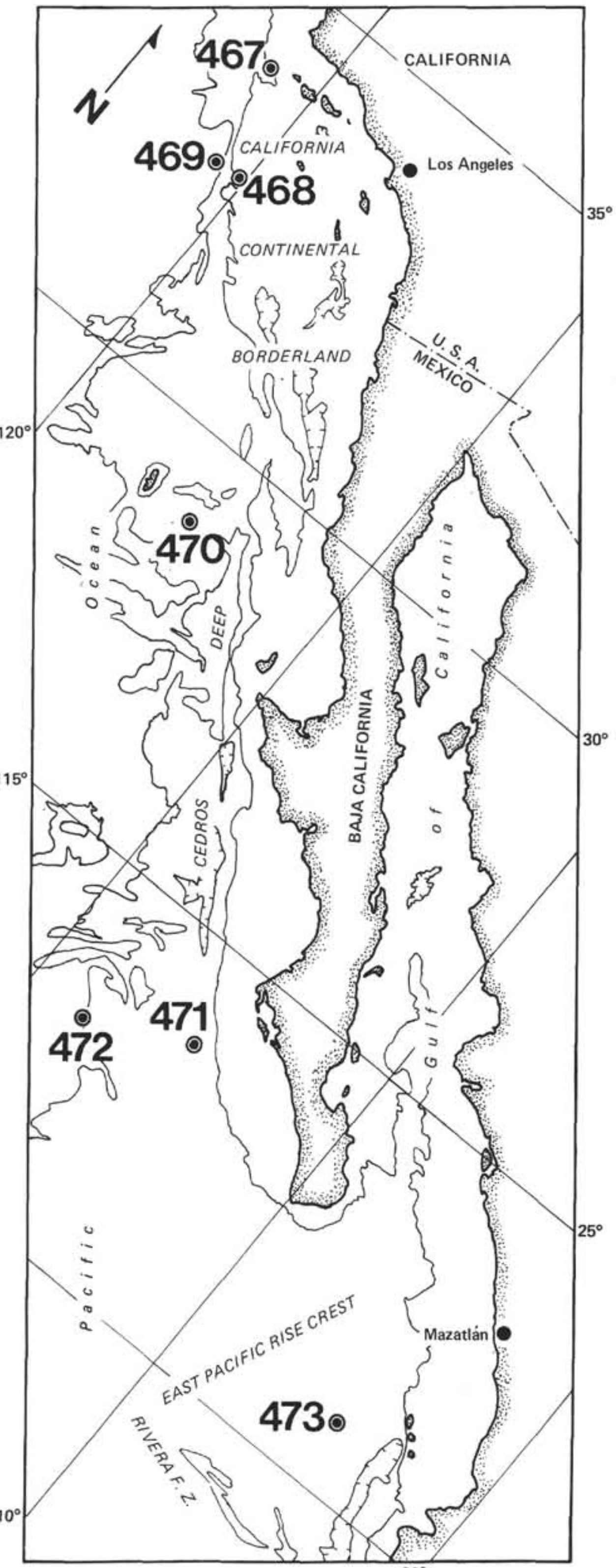

Figure 1. Location of Leg 63 sites.

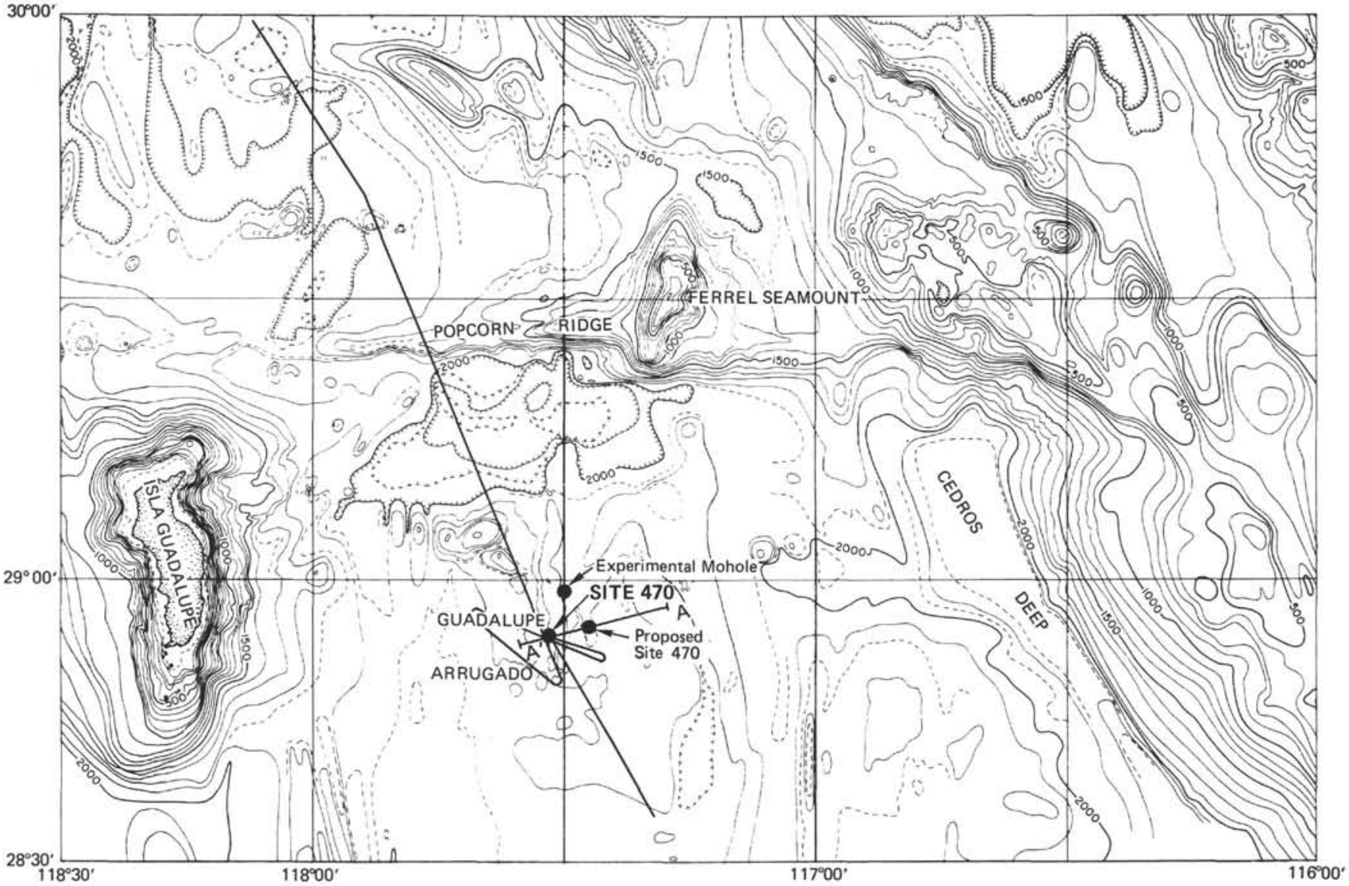

Figure 2. Bathymetric map (from Moore, 1969; also see Krause, 1965) showing locations of Site 470, Experimental Mohole, and approaching *Challenger* seismic line. (Contours are in fathoms. AA' locates the seismic profile shown in Fig. 3.)

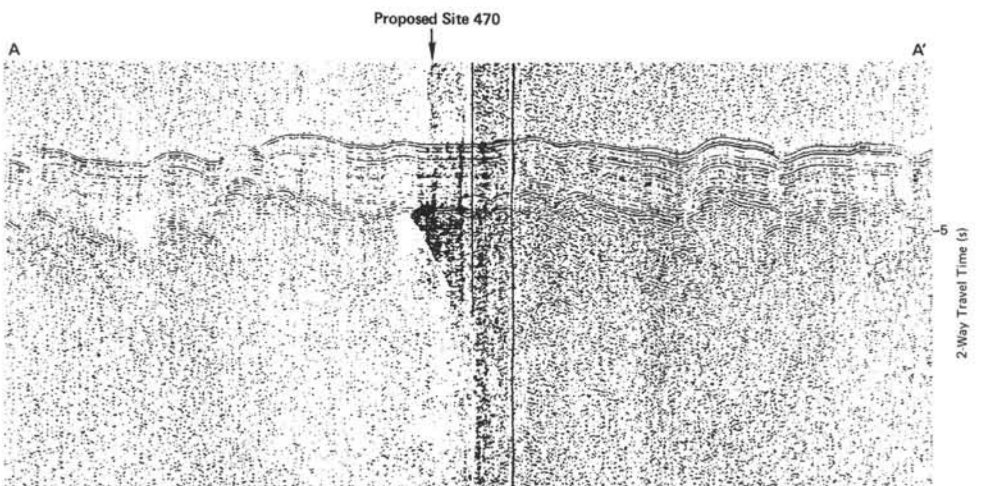

Figure 3. Site survey seismic line showing uniform layer of pelagic sediments over acoustic basement at proposed position of Site 470. (Note that line AA' was run east to west.)

Refraction station FF4 at 29°00′N, 117°29′W, located close to the Experimental Mohole site (Fig. 2), indicates a sediment section 380 meters thick, underlain by 810 meters of transitional crust (5.32 km/s) and 5.13 km of oceanic crust (6.8 km/s) that overlies the mantle (Shor et al., 1969). The average of six heat-flow values in the vinicity of the site is 2.86 HFU (Von Herzen, 1964), and a measurement of 2.81 HFU was obtained in the Experimental Mohole (Von Herzen and Maxwell, 1964). These values are about twice the average value for the Pacific Ocean area. Taylor et al. (1971) correlated linear magnetic anomalies off the west coast of Baja California between 28° and 30°N latitude with the Heirtzler geomagnetic scale and found Anomaly 5A (12 m.y. old) to be the youngest recognizable anomaly west of Baja California between these latitudes. Half-spreading rates in the area were calculated by Taylor et al. (1971) as 1.5 to 1.9 cm/yr.

OPERATIONS

After the postsite survey at Site 469, on 2 November 1978, the *Glomar Challenger* headed south-southeast toward the general area of Site 470, some 80 km east of Guadalupe Island. The underway survey was accomplished with a 40-cubic-inch air gun at a cruising speed of 9.5 knots to a point just north of Popcorn ridge, where speed was reduced to 5.5 knots to obtain a better seismic record.

Our course took us obliquely over the existing single-channel seismic line obtained in 1967 (see Figs. 2 and 3), some 6 km east of the Experimental Mohole site. Just beyond the existing seismic line, we changed course to 318° and then to 100° to survey the area between the proposed Site 470 and an alternative location for this site. After we had selected an appropriate drill site on the excellent seismic record obtained by the *Challenger*, we backtracked our line at a 285° heading, dropping a 13.5-kHz beacon at 2000[3] hours on 2 November (Figs. 4 and 5). After retrieving the gear, we returned to occupy the site over the beacon. The location of the site was approximately 8 km south-southwest of the Experimental Mohole site.

Hole 470 was spudded in 3554.5 meters of water at 0410 hours on 3 November, and a full core barrel was recovered. The coring operations were fairly routine and uneventful. Hole 470 was continuously cored to 168 meters depth (5 m into basalt). Because recovery in the upper Miocene to lower Pliocene part of the section was poor, we decided to pull out and re-spud to recover cores between a sub-bottom depth of 47.5 to 95 meters. Hole 470A was spudded at the same water depth at 0245 hours on 4 November, washed to 47.5 meters, continuously cored to 95 meters depth, washed again to 161.5 meters, and then continuously cored in the basal sediment and the basalt to 215.5 meters total depth (T.D.) until poor hole conditions terminated coring. Recovery was variable (Table 1). Coring rates in the upper three cores containing basalt were very low, but recovery was high, possibly the result of calcite cementing of fractures within the basalt. Coring rates in the bottom two cores were much higher, but high torque and bit-sticking occurred, possibly due to open fractures and rubble falling in the hole above the bit. The basalt consists of altered, fine-grained pillows in the upper part; this portion was cored without problems. But in the lower part, the basalt became more fractured and rubbly. Finally torque increased and the pipe got stuck at 215.5 meters depth at 1030 hours on 5 November. After the pipe was freed and Core 13 of Hole 470A recovered, the hole was flushed with 40 barrels of gel and 20 barrels of My-T-gel, the bit released, and the pipe pulled to 63 meters below the mudline to start logging. Logging attempts were unsuccessful, however, because the logging tool could not clear the end of the pipe, probably owing to the unconsolidated sediment as well as the loss of the hole.

We pulled out of Hole 470A at 0900 hours on 6 November and, after a short postsite survey, proceeded toward Site 471 on a heading of 115°.

LITHOLOGY

Sediments and Sedimentary Rocks

The sediments at Site 470 consist of silty clay and clay grading to diatomaceous clay and diatom-nannofossil ooze with minor vitric ash. Clay, nannofossils, and diatom tests are the major components of these sediments. We distinguished three units on the basis of composition (Table 2; Fig. 6).

Unit 1: Silty Clay and Clay (470—0-68.0 m; 470A—47.5-76 m)

This unit consists mainly of light olive brown to greenish gray silty clay and clay. In the upper part of Hole 470 (Cores 1-3) silty clay is dominant. Subangular quartz, feldspar, and volcanic glass are common constituents of this sediment. Minor components include nannofossils, sponge spicules, glauconite, carbonate, and heavy minerals (including hornblende, pyroxene, zircon, apatite, and pyrite). The lower part of this unit is predominantly olive gray to greenish gray clay. This sediment contains less silt-size detrital quartz and feldspar than does the overlying silty clay. Nannofossils (10-50%) and foraminifers (< 10%) are common components of this clay in Cores 4 and 5.

Vitric ash and pumice lapilli occur as scattered patches throughout this unit. Clear volcanic glass and some angular quartz and plagioclase are components of the ash. Volcanic rock fragments and brown volcanic glass are present in some patches. In addition, pyrite and manganese-oxide streaks are scattered throughout.

Unit 2: Diatomaceous Silty Clay (470—68.0-126.0 m; 470A—76.0-95.0 m)

Dark greenish gray diatomaceous silty clay is the dominant lithology of Unit 2. It is interbedded with minor diatom-nannofossil clay and ooze and light greenish gray nannofossil ooze. The increase in diatoms in Cores 8 (Hole 470) and 3 (Hole 470A) marks the top

[3] All times specified in the text are local times in hours; those in seismic-section figures are Zulu times (Z).

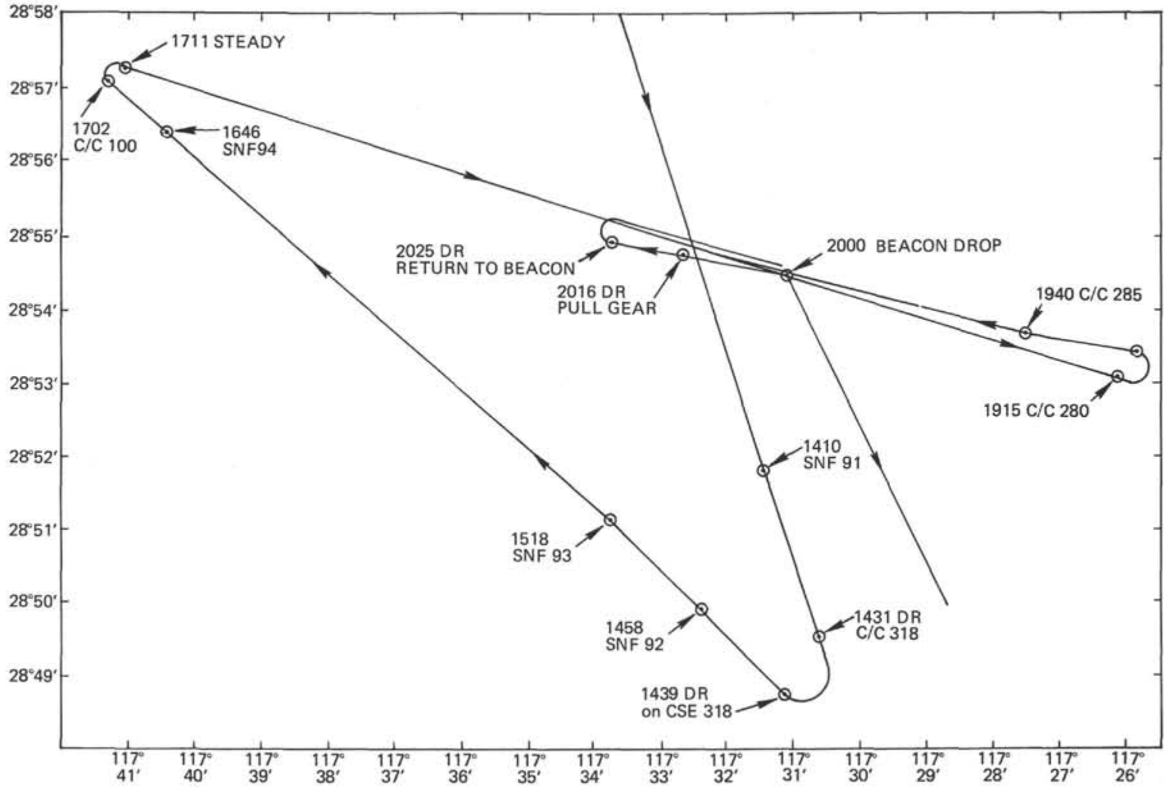

Figure 4. Plots of *Challenger* track lines for on-site survey, Site 470. (SNF = satellite navigation fix.)

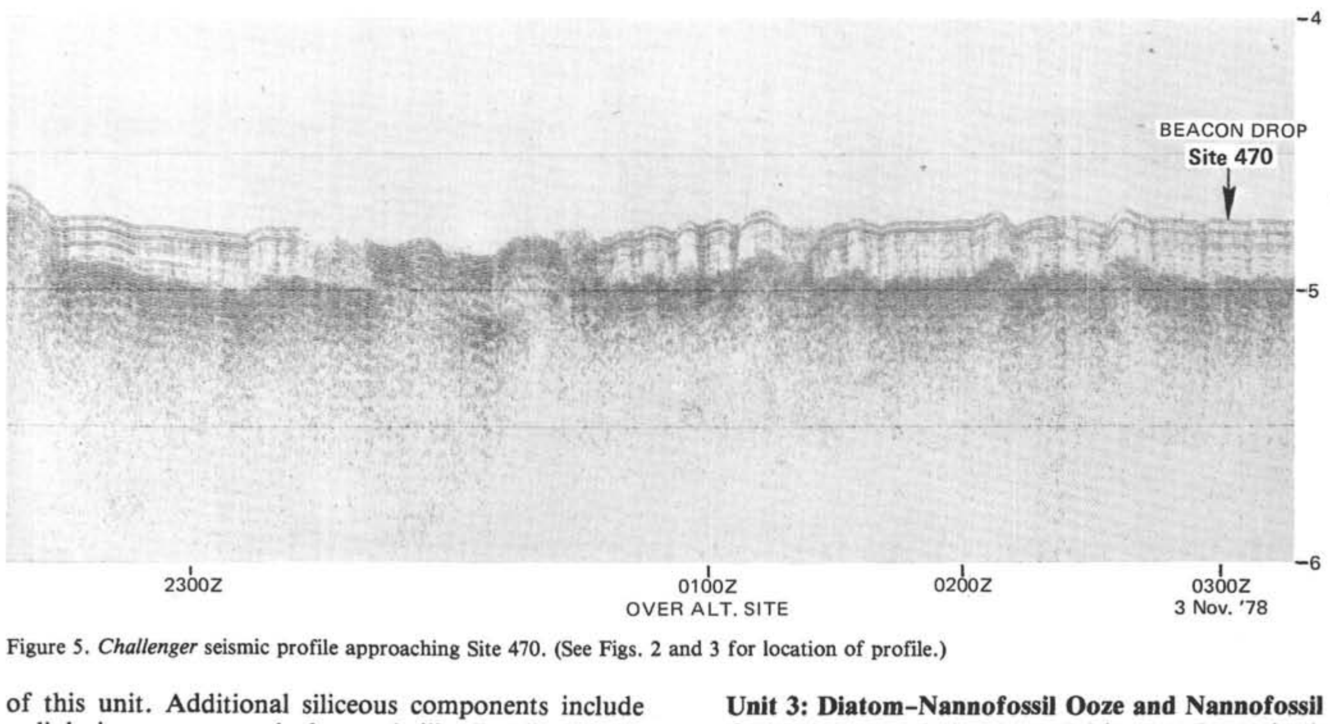

Figure 5. *Challenger* seismic profile approaching Site 470. (See Figs. 2 and 3 for location of profile.)

of this unit. Additional siliceous components include radiolarians, sponge spicules, and silicoflagellates. Detrital components include quartz and feldspar (10–12%). Patches of vitric ash occur near the boundaries of this unit, but pumice lapilli are common throughout. Core 4 (Hole 470A) contains several subrounded rock fragments and two rounded volcanic pebbles. Pyrite and manganese-oxide streaks are scattered throughout.

Unit 3: Diatom-Nannofossil Ooze and Nannofossil Ooze (470—126.0-163.0 m; 470A—161.5-167.0 m)

This unit consists of grayish green diatom-nannofossil ooze and light greenish gray nannofossil ooze. The marked increase in diatoms and nannofossils in Core 14 (Hole 470) defines the top of this unit. Diatoms are common through Core 17 (Hole 470) but absent be-

Table 1. Coring summary, Site 470.

Core No.	Date (Nov. 1978)	Time	Depth from Drill Floor (m)	Depth below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Core Recovered (%)
Hole 470							
1	3	0505	3554.5–3564.0	0.0–9.5	9.5	8.55	90
2	3	0723	3564.0–3573.5	9.5–19.0	9.5	7.60	80
3	3	0820	3573.5–3583.0	19.0–28.5	9.5	4.55	48
4	3	0915	3583.0–3592.5	28.5–38.0	9.5	4.16	44
5	3	1015	3592.5–3602.0	38.0–47.5	9.5	3.61	38
6	3	1120	3602.0–3611.5	47.5–57.0	9.5	2.97	31
7	3	1310	3611.5–3621.0	57.0–66.5	9.5	5.51	58
8	3	1415	3621.0–3630.5	66.5–76.0	9.5	3.80	40
9	3	1510	3630.5–3640.0	76.0–85.5	9.5	3.92	41
10	3	1610	3640.0–3649.5	85.5–95.0	9.5	2.25	24
11	3	1712	3649.5–3659.0	95.0–104.5	9.5	9.83	100+
12	3	1812	3659.0–3668.5	104.5–114.0	9.5	10.14	100+
13	3	1911	3668.5–3678.0	114.0–123.5	9.5	1.73	18
14	3	2015	3678.0–3687.5	123.5–133.0	9.5	2.75	29
15	3	2115	3687.5–3697.0	133.0–142.5	9.5	7.15	75
16	3	2220	3697.0–3706.5	142.5–152.0	9.5	3.87	41
17	3	2332	3706.5–3716.0	152.0–161.5	9.5	4.28	45
18	4	0142	3716.0–3722.5	161.5–168.0	6.5	3.35	52
Total					168.0	90.02	54
Hole 470A							
Wash			3554.5–3602.0	0.0–47.5			
1	4	0455	3602.0–3611.5	47.5–57.0	9.5	5.06	53
2	4	0559	3611.5–3621.0	57.0–66.5	9.5	2.19	23
3	4	0750	3621.0–3630.5	66.5–76.0	9.5	7.50	79
4	4	0905	3630.5–3640.0	76.0–85.5	9.5	9.75	100+
5	4	1000	3640.0–3649.5	85.5–95.0	9.5	1.20	13
Wash			3649.5–3716.0	95.0–161.5			
6	4	1225	3716.0–3721.0	161.5–166.5	5.0	3.86	77
7	4	1520	3721.0–3725.5	166.5–171.0	4.5	3.63	81
8	4	2208	3725.0–3735.5	171.0–180.5	9.5	6.06	64
9	5	0334	3735.0–3744.0	180.5–189.5	9.0	5.84	65
10	5	0506	3744.0–3749.0	189.5–194.5	5.0	0.77	15
11	5	0715	3749.0–3753.0	194.5–198.5	4.0	0.70	18
12	5	0932	3753.5–3762.0	198.5–207.5	9.0	1.15	13
13	5	1255	3762.0–3770.0	207.5–215.5	8.0	0.50	6
Total					101.5	48.21	47

Table 2. Summary of lithologic units, Site 470.

Hole	Lithologic Unit	Core	Depth below Sea Floor (m)	Chrono-stratigraphy	Lithology
470 470A	1	1–8 1–3	0.0–68.0 47.5–76.0	Quaternary–upper Miocene	Silty clay, clay, nannofossil clay; nannofossil ooze, and vitric ash.
470 470A	2	8–14 3–5	68.0–126.0 76.0–95.0	upper Miocene–middle Miocene	Diatomaceous silty clay with minor nannofossil ooze and diatom-nannofossil ooze.
470 470A	3	14–18 6–7	126.0–163.0 161.5–167.0	middle Miocene	Diatom-nannofossil ooze, nannofossil ooze, and clayey dolomitic chalk.

low this. In Core 18 (Hole 470), the nannofossil ooze is firm and lithified to chalk, which is intensely bioturbated and contains several microfaulted laminations. Pyrite and manganese-oxide streaks and patches are scattered throughout. The clayey sediment immediately overlying the basalt at the base of this unit contains abundant dolomite and some pyrite crystals.

Igneous Rocks

All igneous rocks recovered at Site 470 are pillow basalts. Basaltic rocks encountered at Hole 470 are moderately altered pillow lavas and are petrographically very similar to those from the uppermost portion of Hole 470A basalts so that only petrography of the basaltic sequence of Hole 470A is dealt with in the following description.

Figure 7 gives the lithological units distinguished in the basalt sequence of Hole 470A. Twenty-eight basalt units have been defined in Cores 7, 8, and 9; each of these cooling units is bounded at its top and bottom by glassy or fine-grained chilled margins. Cooling Units 1 through 26 range in thickness from 20 cm to 1 meter and are characterized by a curved, dark brown, glassy margin (<1 cm), which generally grades into a narrow, brownish aphanitic zone (2–3 cm in thickness) and then into a porphyritic, fine- to medium-grained interior with greenish, altered olivine phenocrysts (<1.5 mm). The narrow, brownish aphanitic zone is commonly characterized by a subvariolitic to variolitic texture under the microscope. Grain size generally increases toward the interior of each basalt unit, and cracks that developed perpendicularly to the glassy chilled margins are common. All these observations are compatible with the interpretation that Cooling Units 1 through 26 probably represent basaltic pillows or lobes; however, because our observation is limited to the vertical section of the basalt unit, some of the thicker basalt units might rather represent submarine lava flows. Cooling Units 27 and 28 are thicker and coarser-grained than the overlying pillow units and are tentatively interpreted as either extrusive lava flows or thin intrusive sills. The good recovery of Cores 7, 8, and 9 suggests that the basalt units defined above represent a nearly continuous sequence from 167 to 188 meters sub-bottom depth; in fact, although the basaltic rocks from these cores are fragments, most of the fragments from one specific basalt unit may be fit together very well into one original piece. Unfortunately, the recovery rate was very poor in Cores 10 through 13, and we were unable to define any reliable basalt unit below the depth of 189.5 meters.

Rock fragments recovered from the last four cores (10–13) are mainly basalts that commonly show chilled-margin morphology, together with a few pieces of pebble-size limestone. This result may indicate that Cores 10 to 13 (189.5–208.5 m) also penetrated a pile of basaltic pillow lavas intercalated with thin layers or small pockets of carbonate-rich sediments.

On the basis of the general macroscopic observations described above, the basalt sequence of Hole 470A may be divided, although somewhat arbitrarily, into three main sequences: (1) an upper pillow-lava sequence (Cooling Units 1–26); (2) basaltic-lava flows or sills (Cooling Units 27 and 28); and (3) a lower pillow-lava sequence (Fig. 7).

The basalt pillow lavas and pillow fragments from the upper and lower pillow-lava sequences are gray to dark gray and become brownish gray along fractures and veinlets that are commonly filled with calcite. Petrographic study under the microscope indicates that these basalts are for the most part porphyritic, with plagioclase microphenocrysts or plagioclase plus olivine microphenocrysts (0.5–1.5 mm in diameter) set in an intersertal to intergranular groundmass. But the pillow margins and centers are usually characterized by a subvariolitic and subophitic texture, respectively. The olivine microphenocrysts are commonly completely replaced by brownish green clay, calcite, and/or serpentine. The plagioclase microphenocrysts are euhedral and normally zoned from a labradoritic core to a more sodic rim. The groundmass of basalt pillow margins is charac-

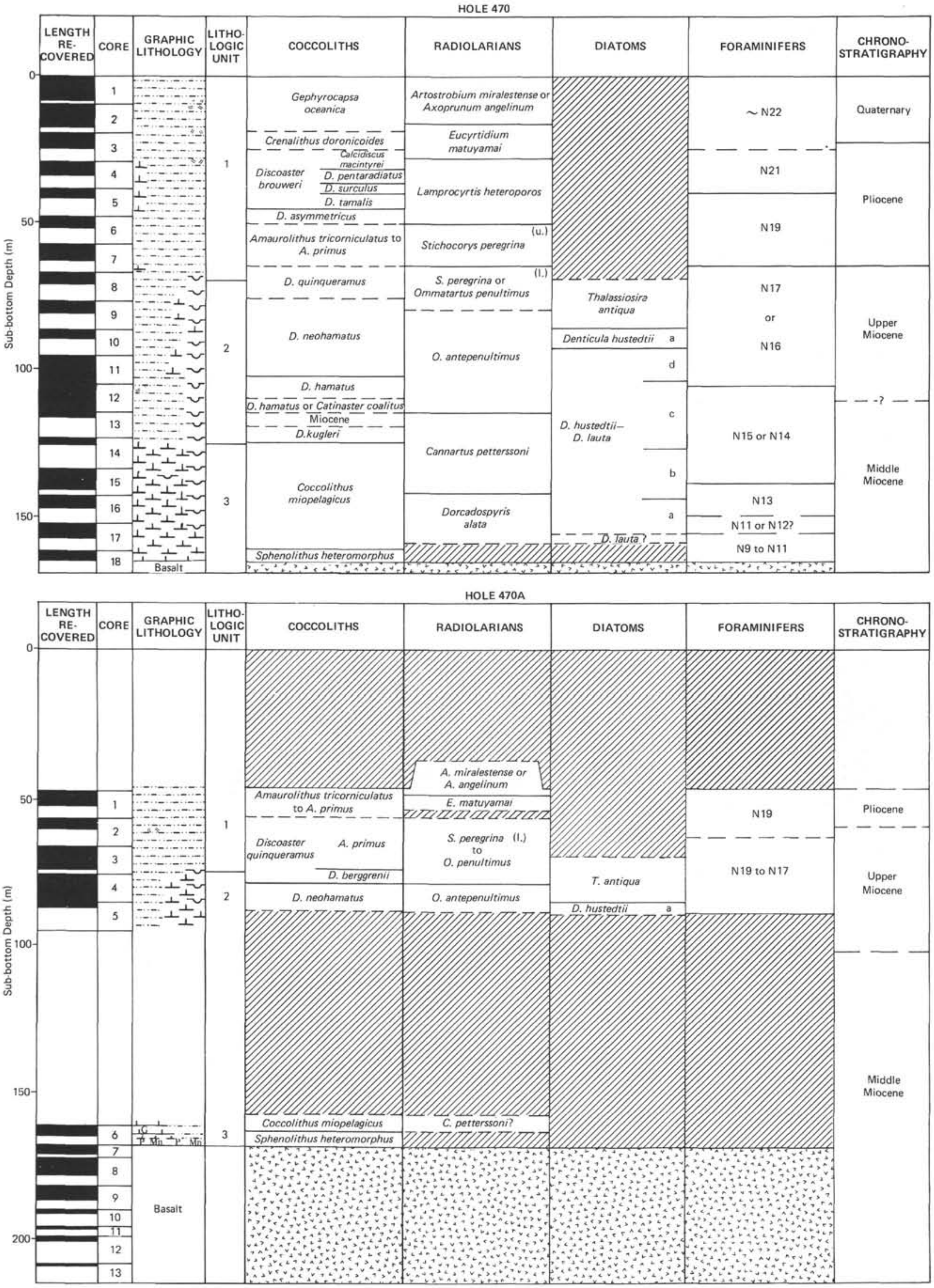

Figure 6. Lithologic and biostratigraphic summary, Site 470.

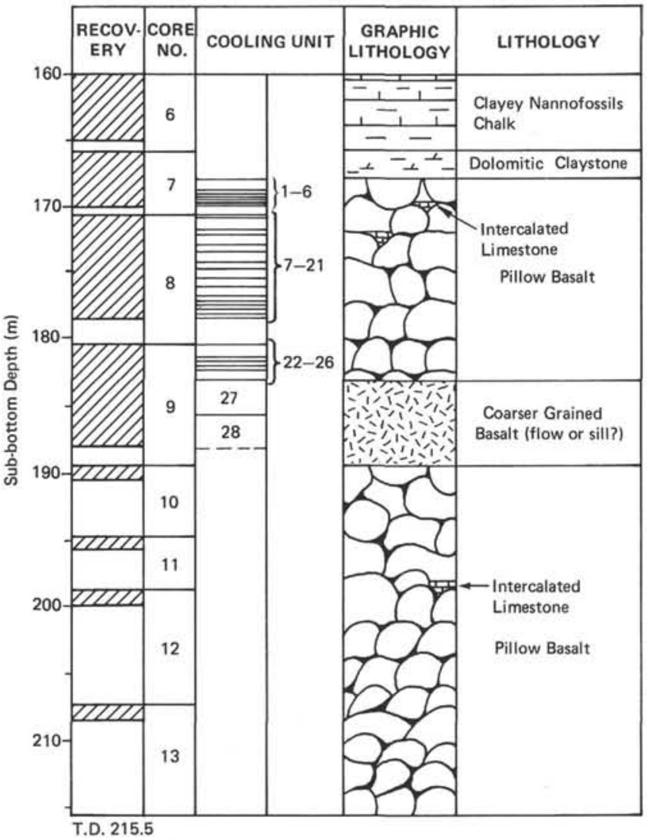

Figure 7. Igneous rock sequence at Hole 470A.

terized by skeletal microlites of plagioclase, feathery and dendritic clinopyroxene, skeletal opaque minerals, and equant olivine set in an altered mesostasis. These quenched mineral morphologies, however, become less prominent toward the pillow interior, where the groundmass is characterized by a subophitic texture, with plagioclase laths embayed in anhedral, larger clinopyroxenes. The specimens from Cooling Units 27 and 28 are petrographically similar to those from the pillow interiors of Cooling Units 1 through 26.

Basalts obtained from Holes 470 and 470A are mostly olivine-plagioclase-phyric basalts; we observed no clinopyroxene as a phenocryst phase. Moreover, olivine is commonly found as one of the groundmass minerals. These petrographic observations suggest that basalts of Holes 470 and 470A were on the olivine-plagioclase cotectic; in comparison to pyroxene-plagioclase-phyric basalts obtained at Site 469, these basalts are more primitive.

BIOSTRATIGRAPHY

The section at Site 470 contains lower middle Miocene to Quaternary microfossil assemblages that are primarily calcareous in the Quaternary and Pliocene but richly siliceous in the Miocene (Fig. 8). Figure 6 shows the microfossil zonal assignments in sediments recovered from Holes 470 and 470A. In Hole 470, the Pliocene/Quaternary boundary is place between Cores 3 and 4 (at about 25 m sub-bottom depth), the Miocene/Pliocene boundary is placed between Cores 7 and 8 (at about 65 m), and the middle Miocene/upper Miocene boundary is interpreted to be in the lower part to the base of Core 12 (at about 110–114 m). Cores 2 through 5 of Hole 470A contain upper Miocene microfossils, whereas possible Quaternary downhole contamination is indicated in Core 1 of Hole 470A by the presence of radiolarian assemblages.

Coccoliths

Lower middle Miocene to Quaternary coccoliths are abundant and moderately well preserved in 25 sediment cores above basalt at Holes 470 and 470A. A limestone within Core 12 of Hole 470A (in the basalt section) contains common but poorly preserved coccoliths of the lower middle Miocene *Sphenolithus heteromorphus* Zone (14 to 15.5 m.y.). The same zone is present directly above basalt. The sequence of coccolith zones at Holes 470 and 470A corresponds closely with the ranges and zones reported at the nearby Experimental Mohole site (Martini and Bramlette, 1963; Martini, 1971; not Martini, fide Schrader, 1974). Correlation of coccolith zones at the Experimental Mohole site (Martini 1971) with those at Site 470 is shown in Figure 9. Close correspondences in the depths reported for key coccolith events by Martini and Bramlette (1963) are shown in Table 3.

The deepest coccolith assemblages above basalt at both holes belong to the *Sphenolithus heteromorphus* Zone. At Hole 470A, the boundary with the overlying *Coccolithus miopelagicus* Subzone (approx. 14 m.y. old) is within Core 6. The sediment in the lower part of Core 6 and in Core 7 contains dolomite rhombs. These are most abundant just above basalt (all coccoliths are missing because of diagenesis) and diminish in size and number upward, so that at 4.4 meters above basalt, the sediment of Sample 470A-6-1, 1 cm (161.5 m sub-bottom depth) is a nearly pure coccolith ooze with no clumped coccoliths or rhombs.

On the basis of common discoasters and sparse *Helicosphaera, Triquetrorhabdulus*, and *Sphenolithus heteromorphus*, middle Miocene assemblages of Holes 470 (Cores 11 to 18) and 470A (Cores 6, 7, 12) indicate a warm, temperate depositional environment (like Site 469). *S. heteromorphus* (with secondary calcite overgrowths) is common only in Sample 470A-7-1, 1 cm (166.5 m), where its enrichment is considered to be a diagenetic effect at the expense of less durable species. Short-ranged *Discoaster kugleri* of the middle Miocene occurs in Sample 470-14-1, 7 cm (124 m) and permits correlation of this site with previously cored sites of DSDP Leg 63 (Hole 467—Core 90, Hole 468B—Core 3, Hole 469—Core 19).

The first record of low-latitude guide species *Catinaster calyculus* Martini and Bramlette s. str. and *Discoaster hamatus* Martini and Bramlette s. str. for Leg 63 permits direct identification of part of the *Discoaster hamatus* Zone between Sample 470-13-1, 23 cm (114 m) and Section 470-11-6 (104.5 m). The upper Miocene *Discoaster neohamatus* Zone and *Discoaster quinqueramus* Zone also contain more common warm-water

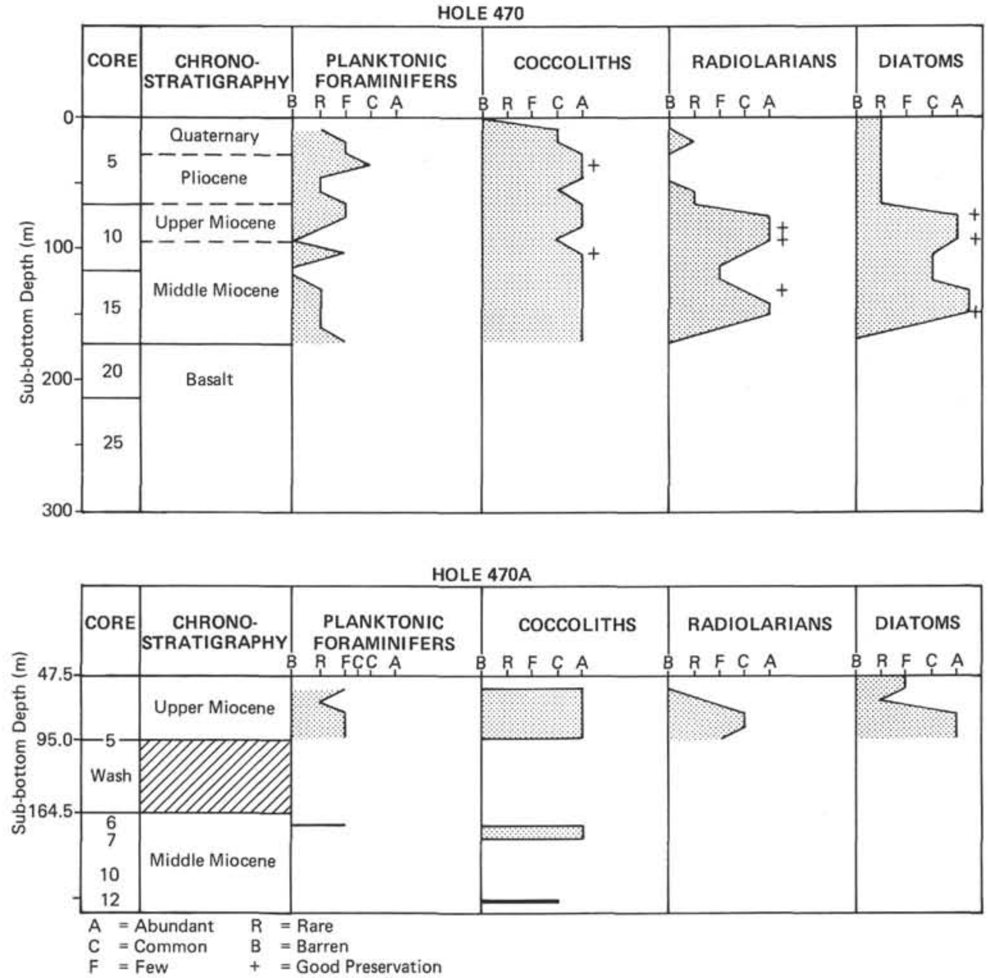

Figure 8. Plots of relative abundances of planktonic microfossils at Site 470.

species that persist through thicker intervals than at Sites 467 through 469. Cool-water coccolith facies rich in *Reticulofenestra, Discoaster intercalaris* Bukry, and *D. variabilis* Martini and Bramlette, however, are interspersed throughout these zones. Highlights of the upper Miocene, which was cored a second time at Hole 470A to fill in gaps for detailed studies, include the first reports of *Catinaster mexicanus* Bukry from the west coast of Mexico (Sample 470A-3,CC to Section 470A-4-6). This rarely reported species was first described from DSDP Leg 1 cores from the Gulf of Mexico. The presence of large-sized *Discoaster quinqueramus* Gartner is established for the first time within the Guadalupe area in Section 470-8-1.

The enigma of the calcareous Miocene/Pliocene boundary for Leg 63 persists through Site 470. The interval between the *Amaurolithus primus* Subzone and the *A. tricorniculatus* Zone that includes the boundary cannot be subdivided, because the cool-water coccolith assemblages lack the key guide fossils—persistent *D. quinqueramus* and any *Amaurolithus amplificus* (Bukry and Percival) in the *A. primus* Subzone, and any *Triquetrorhabdulus rugosus* Bramlette and Wilcoxon, *Ceratolithus acutus* Gartner and Bukry, or *C. rugosus* Bukry and Bramlette in the *A. tricorniculatus* Zone.

The Pliocene section, according to the coccolith record, begins with the *Discoaster asymmetricus* Subzone in Section 470-6-2. The Pliocene assemblages are warm temperate, containing a few *C. rugosus* in the *Discoaster tamalis* Subzone, abundant *Discoaster pentaradiatus* Tan in the *Discoaster pentaradiatus* Subzone, but *Coccolithus pelagicus* (Wallich) throughout. The top of the Pliocene is practically in Core 3 (Hole 470), on the basis of the last common occurrence of *Discoaster brouweri* Tan and *D. triradiatus* Tan in Sample 470-4-1, 30 cm (29 m) (Haq et al., 1977). *Cyclococcolithina macintyrei* (Bukry and Bramlette), which marks the top of the Pliocene in the Mediterranean region (Bizon and Müller, 1978) and persists through the *Emiliania annula* Subzone (Bukry, 1973), is common in Sample 470-3,CC but missing in Sample 470-2,CC.

The Quaternary coccolith assemblages in Cores 1 through 3 (Hole 470) are low-diversity temperate assemblages characterized by *Coccolithus pelagicus, Cyclococcolithina leptopora* (Murray and Blackman), *Emiliania annula* (Cohen), *E. ovata* Bukry, *Gephyrocapsa*

SERIES OR SUBSERIES	ZONE OR SUBZONE	EXPERIMENTAL MOHOLE	HOLE 470	HOLE 470A
Quaternary	*Emiliania ovata*	Washed	1, CC–2, CC	Washed
	E. annula	Washed	3, CC	
Pliocene	*Cycloccolithus macintyrei*	—	4-1–4-2	
	Discoaster pentaradiatus	—	4-3–4, CC	
	D. surculus	—	5-1	
	D. tamalis	—	5-3	
	D. asymmetricus	—	6-2	Washed
	Amaurolithus primus–A. tricorniculatus	—	6, CC	1-1–1, CC
upper Miocene	*A. primus*	—	8-1	2-1–3-6
	Discoaster berggrenii	—	8, CC(?)	3, CC
	D. neorectus	8-10 (383–384)	9, CC–10-2	3, CC–4, CC
	D. bellus			5-1–5, CC(?)
	D. calyculus	8-11 (286)–8-12 (226–229)	11, CC–13-1	Washed
	Helicosphaera carteri	8-11 (70–72)(?)	—	Washed
	D. kugleri	8-14 (384–387)	14-1	Washed
	Coccolithus miopelagicus	8-15 (34–37)–7-5 (5)	14,CC–17, CC	6-1
	Sphenolithus heteromorphus	—	18-1–18-2	6-2–12-1[a]

[a] Brackets basalt recovered in Cores 7 to 11.

Figure 9. Coccolith zonation for the Experimental Mohole site and Site 470.

Table 3. Coccolith correlations at Guadalupe sites.

	EM[a]		DSDP Hole 470	
Coccolith Event	Core	Depth (m)	Core	Depth (m)
Highest *Discoaster hamatus*	11	95–105	11	95–104.5
Lowest *Catinaster calyculus*	13	113–122	13	114–123.5
Lowest *Discoaster kugleri*	14	122–131	14	123.5–133.0

[a] Experimental Mohole, see Martini and Bramlette, 1963.

caribbeanica Boudreaux and Hay, *G. oceanica* Kamptner, and *Helicosphaera carteri* (Wallich).

Silicoflagellates

Silicoflagellates are sparse or absent in the Quaternary and Pliocene of Cores 1 to 7, Hole 470, and Cores 1 and 2, Hole 470A. They are few to common in the upper Miocene diatomaceous sediment of Cores 8 to 10, Hole 470, and Cores 3 to 5, Hole 470A. The occurrences of *Dictyocha fibula* Ehrenberg s. ampl., *D. pulchella* Bukry, and *Distephanus pseudofibula* (Schulz) in most samples from the upper Miocene suggest warm to temperate depositional conditions. The middle Miocene has few to common silicoflagellates in Cores 11 to 17, Hole 470. We recorded common occurrences of *Distephanus* sp. cf. *D. longispinus* (Schulz) in Section 470-13-1, *D. speculum hemisphaericus* (Ehrenberg) in Sample 470-16,CC, and *Mesocena elliptica* (Ehrenberg) in Sample 470-17,CC. *Corbisema triacantha* (Ehrenberg) is recorded from Sample 470-16,CC to Section 470-13-2, which is above the level of the coccolith *Discoaster kugleri* Subzone (Section 470-14-1). This phenomenon could indicate some reworking, because *C. triacantha* ranges only as high as *D. kugleri* at the Experimental Mohole site (Martini, 1971; Bukry and Foster, 1973) and is considerably lower at warm-water Site 158 in the eastern Pacific (Bukry, 1973; Bukry and Foster, 1973). But the percentages of *C. triacantha* show a general decline upward, which suggests the extinction of the species here: 23% in Core 17, 4% in Core 16, 10% in Core 15, 14% in lower Core 14, 4% in upper Core 14, 2% in lower Core 13, and 0% in upper Core 13 and in Core 12.

Radiolarians

Few to abundant middle Miocene through Quaternary radiolarians of moderate to good preservation were recovered from Cores 7 through 17 in Hole 470 (lower Pliocene through middle Miocene) and from Section 1-3 through Core 5 in Hole 470A (lower Quaternary and upper Miocene). Section 1-3 through Core 6 of Hole 470 and Section 1-1 of Hole 470A yielded rare, poorly preserved radiolarians. In Hole 470, Section 1 in each of Cores 1, 4, and 5 as well as Section 2 of Core 18 are barren.

Except for Core 2, Section 5, the upper layers of Hole 470 from Cores 1 through 6 are so poor in radiolarians that no zonal classification is possible. Section 2-5 is assigned to the lower Pleistocene *Eucyrtidium matuyamai* Zone, because it contains rare to few individuals of the zone fossil itself and of *Lamprocyrtis neoheteroporos* and *L. heteroporos*, as well as rare members of the equatorial species *Ommatartus tetrathalamus, Spongaster tetras*, and *Theocorythium vetulum*. We encountered a very thin cover of Quaternary sediments at Hole 470A. Sediments below the uppermost Section 1 of Core 1, which contains nondiagnostic radiolarians only and is tentatively assumed to have been deposited in the late Quaternary, can be assigned to the lower Quaternary *E. matuyamia* Zone, for these sediments simultaneously yielded *Lamprocyrtis neoheteroporos* and *L. heteroporos*.

There are enough equatorial species in the Pliocene and Miocene cores of Hole 470 to permit recognition of equatorial zones. The first rare appearance of *L. heteroporos*, the last occurrences of *Stichocorys peregrina*, and the absence of diagnostic Pleistocene and Miocene species indicate deposition in the early Pliocene for Section 6-2 through Core 7 of Hole 470 (assigned to the upper part of the *S. peregrina* Zone). The Miocene/Pliocene boundary is placed between Cores 8 and 7 below the first appearance of *L. heteroporos* that follows in that region, immediately above the last occurrence of *Ommatartus penultimus*. In Hole 470A, the upper part of *S. peregrina* Zone could not be recognized.

The upper Miocene, lower part of the *S. peregrina* Zone cannot be separated from the underlying *Ommatartus penultimus* Zone. Both of these zones are represented from Section 8-1 through Section 9-1 of Hole 470 and from Section 2-1 through Section 4-3 of Hole 470A. This interval is distinguished by few to abundant *S. peregrina* and by rare individuals of *O. penultimus*. Besides several nondiagnostic radiolarians, there are rare to abundant occurrences of *Lithopera neotera* and *Stichocorys wolffii*, which are probably reworked. *Stichocorys delmontensis* joins the assemblage in the lower part of the uppermost Miocene section.

According to Riedel and Sanfilippo (1978) and in accordance with Kling (1973), the *O. antepenultimus* Zone is defined by the evolutionary bottom and the morphotypic top of *O. hughesi*. Consequently, the lower boundary of the lower upper Miocene *O. antepenultimus* Zone can tentatively be placed between the main occurrences of *O. hughesi* and *Cannartus petterssoni* in Hole 470 (either below Section 12-1 or below Section 12-7). Various species of *Cyrtocapsella, Lithopera*, and *Stichocorys delmontensis* and *S. wolffii* complete the radiolarian assemblage of the *O. antepenultimus* Zone. The succession of Hole 470A ends with Core 6 in the lower upper Miocene *C. petterssoni*? Zone immediately above basalt.

The boundary between middle and upper Miocene is thus defined by the first appearance of the typical *O. hughesi* (below Section 12-7). The transition between *Cannartus petterssoni* and *O. hughesi* cannot always be clearly recognized, however, and it is sometimes difficult to separate one species from the other. The upper middle Miocene *C. petterssoni* Zone comprises Sections 13-1 through 15-5 at Hole 470. Its lower boundary is defined by the first appearance of *C. petterssoni*, which is associated with *Cannartus laticonus*, various species of *Cyrtocapsella, Lithopera*, and *Stichocorys*.

The lowermost part of the succession encountered at Hole 470 (Sample 15,CC through Core 17) contains few to abundant, well preserved radiolarians of the lower middle Miocene *Dorcadospyris alata* Zone, including *Cannartus laticonus*, various species of *Cyrtocapsella, Lithopera*, and *Stichocorys*, etc. without *Cannartus petterssoni*. Core 18, immediately overlying the basalt, is barren.

Diatoms

Abundant to common middle to upper Miocene diatoms were recovered at Site 470. Diatoms are generally rare and non-age diagnostic in post-Miocene sediments, with the exception of Sample 470-2,CC, where the Quaternary diatoms *Rhizosolenia curvirostris* and *Pseudoeunotia doliolus* are present.

In Hole 470, diatoms increase abruptly in abundance downhole in Section 8-2 (and in Core 3 of Hole 470A) and are abundant to common through Core 17. The interval from Sample 470-8-2, 12–14 cm through Sample 470-9,CC is assigned to the upper Miocene *Thalassiosira antiqua* Zone. Samples 470-10-1, 40–42 cm through 470-10-2, 73–75 cm contain diatoms that are characteristic of the lower part of Subzone a of the *Denticula hustedtii* Zone (*Coscinodiscus temperei*, sensu Schrader [1973], and *C. endoi*).

The interval from Samples 470-11-1, 40–42 cm through 470-17-3, 79–80 cm is correlated with the *Denticula hustedtii–D. lauta* Zone. This interval is further subdivided into the following subzones: Subzone d (Sample 470-11-1, 40–42 cm through 470-11-5, 40–42 cm); Subzone c (Samples 470-11,CC through 470-14-2, 40–42 cm); Subzone b (Samples 470-15-1, 40–42 cm through 470-16-1, 40–42 cm); and Subzone a (Samples 470-16-2, 40–42 cm through 470-17-3, 79–80 cm). Sample 470-17,CC is tentatively placed into the underlying *Denticula lauta* Zone. The middle Miocene/upper Miocene boundary presumably lies near the base of Core 11 and the top of Core 12.

In Hole 470A, the interval from Samples 470A-3-5, 40–42 cm through 470A-4,CC is assigned to the *Thalassiosira antiqua* Zone. Diatom assemblages in Core 5 correlate with the lower part of Subzone a of the *Den-*

ticula hustedtii Zone and are equivalent to those of Core 10 of Hole 470.

Foraminifers

Planktonic foraminifers are sparse and moderately well preserved in most samples examined from Site 470.

Taxa present in Quaternary assemblages in Samples 470-1,CC through 3,CC include *Globigerina bulloides, Orbulina universa, Globorotalia inflata*, and *Neogloboquadrina dutertrei. Neogloboquadrina atlantica, Orbulina universa*, and *Globigerinoides bulloides* are consistent elements of the faunas in Pliocene Samples 470-4,CC through 7,CC and 470A-1,CC and 2,CC. Sample 470-4,CC, which contains *Globorotalia inflata*, is assigned to the upper Pliocene (Zone N21) and Sample 470-7,CC, which contains *Globorotalia crassaformis, G. puncticulata*, and *G. conomiozea*, is identified as part of the lower Pliocene (Zone N19). Foraminifers from Samples 470-5,CC and 470-6,CC, and from Samples 470A-1,CC and 470A-2,CC lack taxa that allow recognition of upper versus lower Pliocene. The sporadic occurrence of *Neogloboquadrina pachyderma* (s.l.) in Cores 8 through 11 of Hole 470 allow assignment of this interval to the upper Miocene. Samples from Cores 14 through 16 are assigned to Zones N11 to N12 because of the occurrence of *Globigerina druryi* in Samples 470-14,CC and 470-16,CC and of *Globorotalia praefohsi* in Sample 470-14,CC. Sample 470-17-2, 30–32 cm contains *Globorotalia peripheroronda, G. peripheroacuta*, and *Orbulina universa* and is assigned to Zone N10. Samples 470-18,CC and 470A-6,CC contain *Orbulina universa* and *Globorotalia peripheroronda* without *G. peripheroacuta* and are thus assigned to Zone N9.

Benthic foraminifers are sparse but well preserved in samples from Site 470. Taxa present suggest deposition in mid- to lower-bathyal water depths.

SEDIMENT ACCUMULATION RATES

The sediment accumulation rate curve for Hole 470 (Figure 10) was constructed from selected coccolith (C), radiolarian (R), diatom (D), and planktonic foraminiferal (F) events. The plot suggests rates of about 17 m/m.y. for the Quaternary and late Pliocene, about 10 m/m.y. for the early Pliocene, and about 12 m/m.y. for the late and middle Miocene. Microfossil evidence argues for a latest Miocene hiatus of about 2.5-m.y. duration in Core 8 of Hole 470. The presence of the diatom *Thalassiosira burckliana* in Sample 470-8-2, 12–14 cm indicates an age of about 7.6 m.y. or older. Section 8-1 is assigned to the uppermost Miocene *Amaurolithus primus* Subzone of the *Discoaster quinqueramus* Zone (coccolith) (about 6.5 to 5.1 m.y. old); however, the immediately overlying sediments in Core 7 contain lower Pliocene radiolarians and planktonic foraminifers. A lithologic change from clay in Section 470-8-1 to diatomaceous silty clay in Section 470-8-2 corresponds with this latest Miocene hiatus.

PHYSICAL PROPERTIES

Figure 11 summarizes the physical-properties data for the two holes drilled at Site 470. These are plotted together because the sediment/basalt contact in Hole 470A is only about 4 meters deeper than in Hole 470.

The density and velocity profiles clearly define two units—a sedimentary one and a basaltic one. The upper unit, about 164 meters thick, is soft silty clay, nannofossil ooze, and diatomaceous nannofossil clay having nearly invariant density and velocity values (Table 4). The slight increase in density from 1.5 g/cm^3 at 154 meters to 1.7 g/cm^3 at 162 meters corresponds to an increase in dolomite in the sediments overlying the basalt. At the nearby Mohole site, Hamilton (1965) reported an average density and velocity of 1.45 g/cm^3 and 1.56 km/s, respectively, for an identical section of sediments (compare with values in Table 4). We made no shear-strength measurements in these sediments, because nearly all were completely homogenized by drilling. However, for similar sediments recovered at the Mohole site, Moore (1964) reported shear-strength values between 30 and 90 mbars, indicating high disturbance. Porosity averages about 72% for the sediments at Site 470. This average may be slightly low, because we used a grain density of 2.7 g/cm^3 to calculate porosity. Hamilton (1965) reported a slightly lower average grain density (2.57 g/cm^3) and higher porosity (74%). Sonic (compressional) velocity of the sediment at Site 470 averages 1.51 km/s with little variation (Table 4). Hamilton (1965) reported an average velocity of 1.56 km/s for the sediments at the Mohole site.

The density (2.77 g/cm^3) and velocity (5.49 km/s) of the basalt contrast sharply with the values for the overlying sediment. These values match those reported by Somerton et al. (1963) for basalt from the Mohole site (2.82 g/cm^3 and 5.76 km/s, respectively). The variations in both density and velocity of these basalts (Fig. 11) perhaps indicate fracturing or weathering. The impedance contrast for the boundary between the sediments and basalt is 0.74.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

The correlation of the lithology at Site 470 with the seismic-reflection profile obtained by the *Glomar Challenger* approaching Site 470 (Fig. 5) is shown in Figure 12. The seismic-reflection record shows two sets of strong, continuous, paired reflectors above acoustic basement. Between the sea floor and these two strong reflecting horizons are zones of weak, indistinct, and discontinuous reflectors.

The upper acoustic unit (down to the first pair of strong reflectors) correlates with the Quaternary silty clay of Lithologic Unit 1. Pliocene silty clay, nannofossil clay, and ooze that make up the lower part of Lithologic Unit 1 appear as the weak reflectors between the two sets of paired, strong reflectors. The lower acoustic unit (between the lower paired reflectors and acoustic basement) is mainly transparent, but occasionally shows weak, intermittent reflecting horizons. Lithologic Units 2 and 3, which consist mainly of silty clay interbedded with nannofossil ooze and a short interval of silty claystone at the base, produce this mainly transparent unit. The strong reflector at 0.21 s marks the top

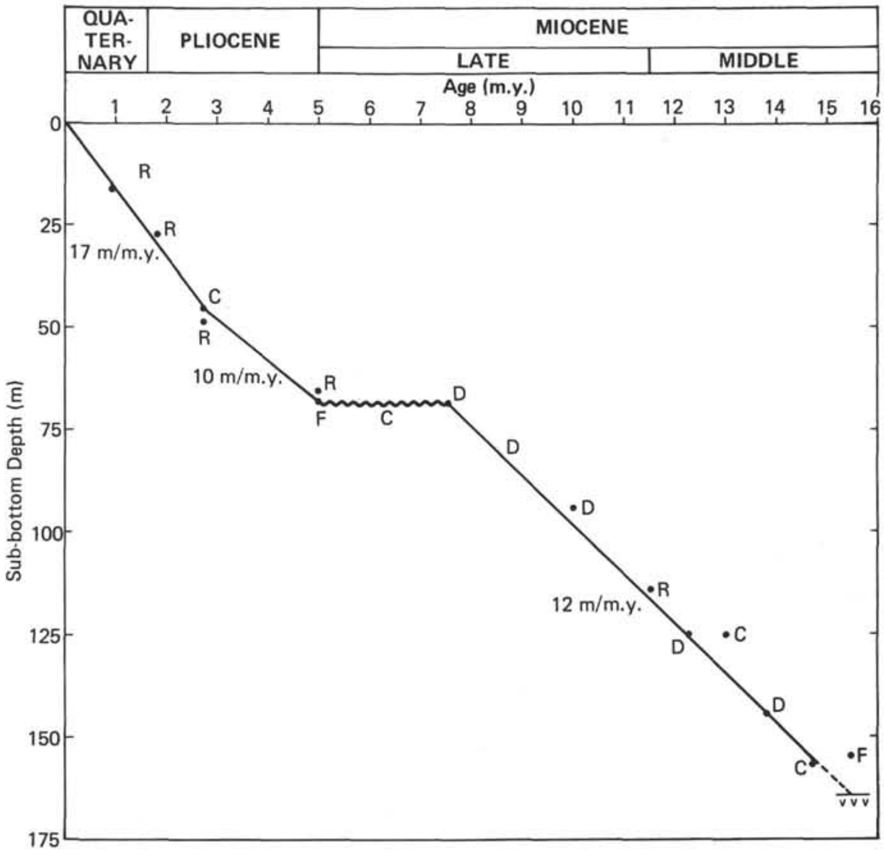

Figure 10. Sediment accumulation rates for Hole 470. (The curve was constructed from selected coccolith [C], radiolarian [R], diatom [D], and planktonic foraminiferal [F] events.)

of acoustic basement and correlates with the basalt cored in the lower part of Holes 470 and 470A.

CONCLUSIONS

1. At Site 470 off Guadalupe Island, Leg 63 achieved a more complete fossil record than that obtained at the Experimental Mohole site. The Site 470 biostratigraphic record is apparently complete, except for a hiatus in the late Miocene (from 5 to about 8 m.y. ago). The diatom record is restricted to the Miocene sequence below this hiatus.

2. The uppermost Miocene to Quaternary section is more terrigenous above this hiatus than below. The section above the hiatus was only sparsely sampled at the Experimental Mohole site. A lower siliceous component above the hiatus may reflect lower productivity. Alternatively, the increase in terrigenous matter upsection may indicate an increase in tectonism or possibly climatic fluctuations.

3. Coccoliths and planktonic foraminifers suggest that the age of sediments at the basement contact is 15 to 16 m.y. This is concordant with the basement age estimated from striped magnetic anomalies (15 m.y. old) and the 15 ± 7 m.y. K-Ar date of Krueger (1964) from the Experimental Mohole. The basement consists of three stratigraphic sequences. The upper sequence extends to 183 meters sub-bottom depth and consists of at least 26 cooling units (pillows) with glassy quenched margins and coarse-grained centers with phenocrysts. The middle sequence, occurring from 183 to about 189 meters depth, consists of at least two cooling units of massive, coarser-grained basalt or diabase—either massive flows or sills. The lower part of the basement is a pillow basalt sequence similar to the upper one, but poor core recovery precluded the recognition of individual pillows.

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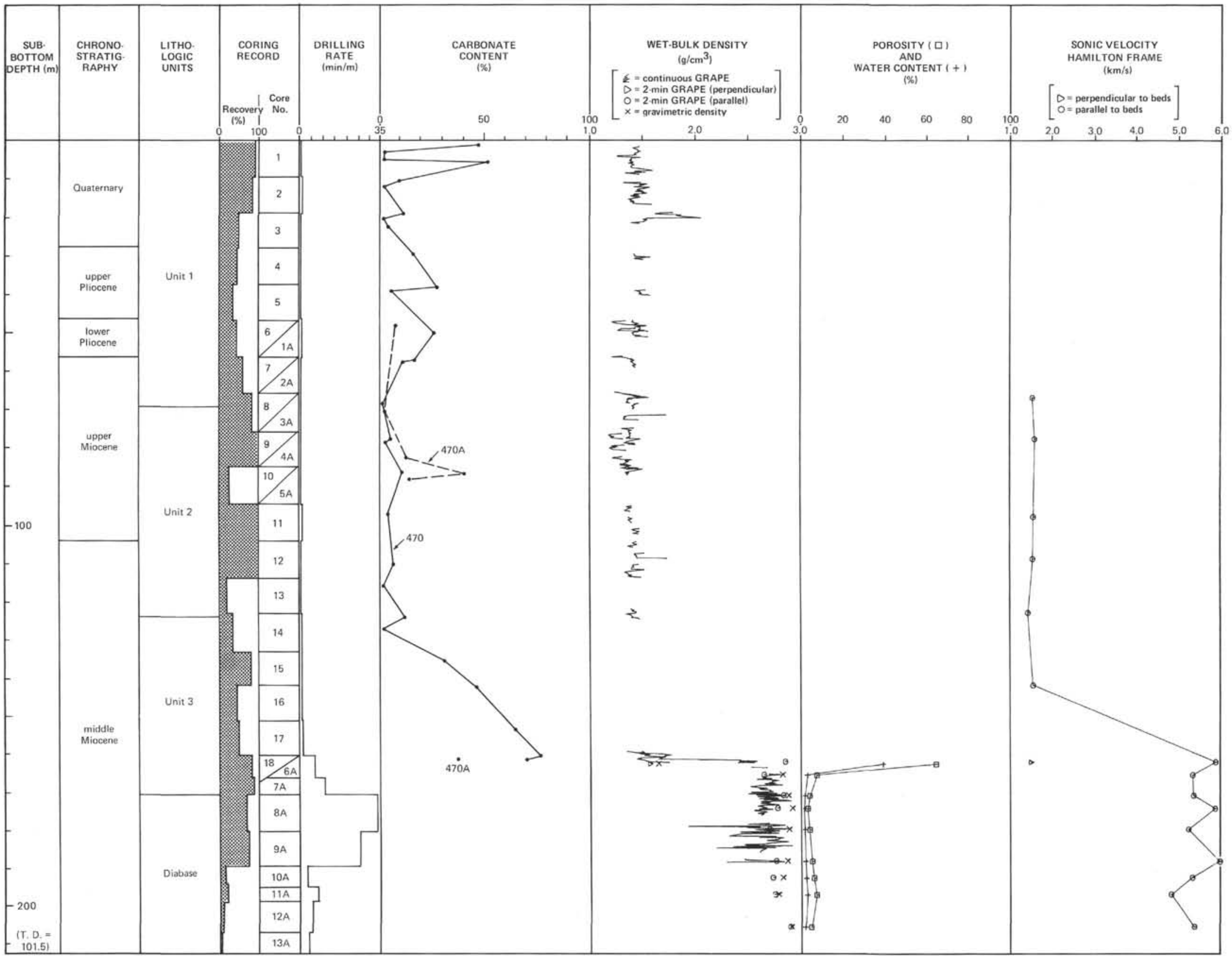


Figure 11. Summary of physical properties, Site 470.

Table 4. Average densities and velocities, Holes 470 and 470A.

Lithology	Depth Interval (m)	Density (g/cm^3) Range	Density (g/cm^3) Average	Velocity (km/s) Range	Velocity (km/s) Average
Sediment	0–165	1.5–1.7	1.5	1.42–1.54	1.51
Basalt	165–T.D.	2.65–2.90	2.77	4.86–6.00	5.49

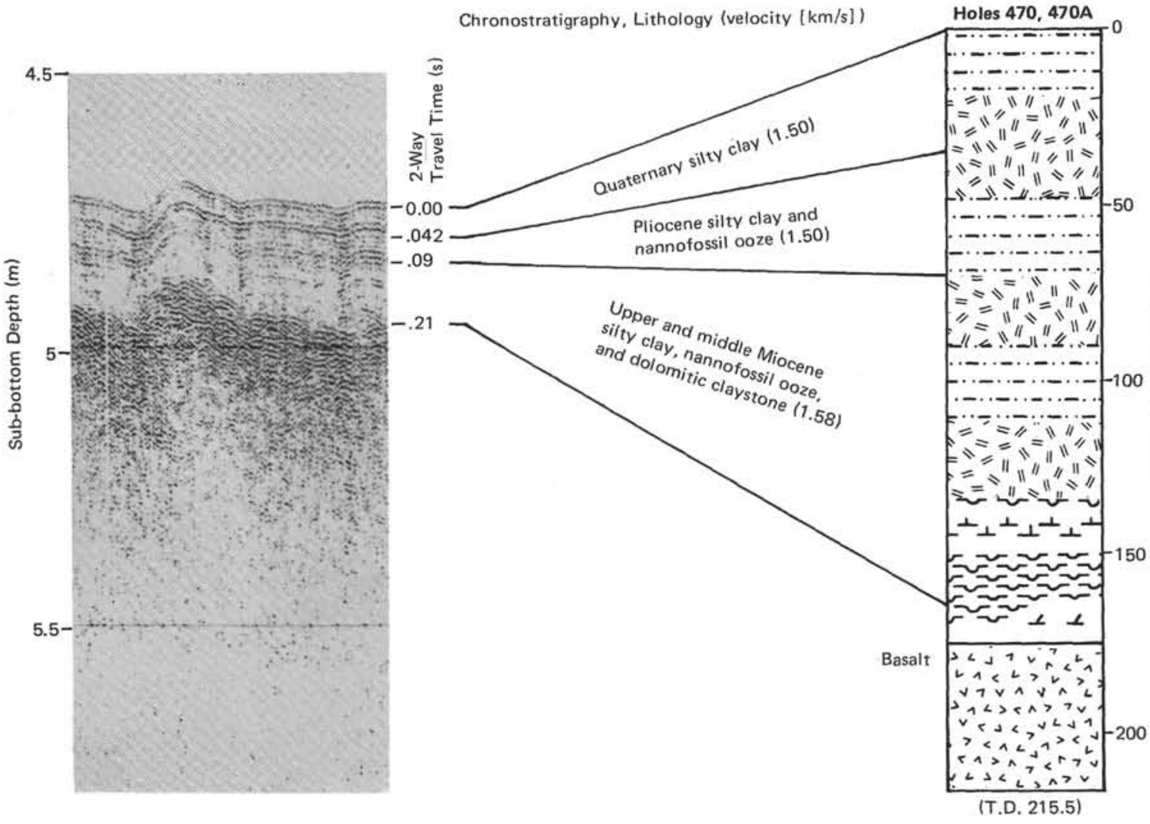


Figure 12. Correlation of *Challenger* seismic-reflection profile with lithologic units, Site 470.

SITE 470 HOLE CORE 1 CORED INTERVAL 0.0–9.5 m

TIME – ROCK UNIT: QUATERNARY

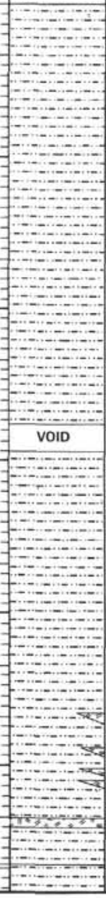
BIOSTRATIGRAPHIC ZONE: *Emiliania ovata* (N); N.22 (F)

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS B, B, B, CM; RADIOLARIANS *Artostrobium miralestense* or *Axoprunum angelinum* zone (R), B; DIATOMS RP

SECTION: 1, 2, 3, 4, 5, 6, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

5Y 5/6

Nannofossil-rich(?)

Color change 5GY 4/1

To base of core

Nannofossil-rich(?)

Common patches of volcanic ash

Sharp contacts

SILTY CLAY, light olive brown (5Y 5/6) near top of core chanigng to medium greenish gray (5GY 4/1) in Section 2. Brown and olive gray mottles scattered throughout Section 1. Layer of light greenish gray (5G 8/1) **VITRIC ASH** occurs in Section 6; several scattered patches of ash Sections 5–6. Carbonate-rich zones in Sections 1 and 3 (see carbonate bomb data) may contain abundant nannofossils; no color change accompanies. Scattered pyrite(?)-rich streaks and patches throughout. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

	1-80	2-129	3-84	3-110
% Organic Carbon	–	–	0.34	–
% $CaCO_3$	47	3	3	52

SMEAR SLIDE SUMMARY

	1-46 (D)	5-148 (M)
TEXTURE:		
Sand	2	5
Silt	25	95
Clay	73	5
COMPOSITION:		
Quartz	15	–
Feldspar	5	1
Mica	1	TR
Heavy minerals	1	TR
Clay	73	TR
Volcanic glass	5	99
Pyrite	TR	TR
Carbonate unspec.	TR	–

SITE 470 HOLE CORE 2 CORED INTERVAL 9.5–19.0 m

TIME – ROCK UNIT: QUATERNARY

BIOSTRATIGRAPHIC ZONE: N.22 (F); QUATERNARY (D); *Emiliania ovata* (N)

FOSSIL CHARACTER: FORAMINIFERS FM; NANNOFOSSILS CG, CM; RADIOLARIANS *Artostrobium miralestense* or *Axoprunum angelinum* zone (R), *Eucyrtidium matuyamai* zone (R), RP; DIATOMS RM

SECTION: 1, 2, 3, 4, 5, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES (IW, OG)

LITHOLOGIC DESCRIPTION

Ash patches

Sandy patches

Sandy patches

Scattered sandy patches

SILTY CLAY, medium grayish olive (10Y 4/2) to grayish green (5G 5/1) with olive gray mottles (5Y 3/2). Scattered patches of dark green gray (5GY 4/1) **SANDY ASH** and light gray (N7) **VITRIC ASH.** Sandy ash contains abundant volcanic lithic fragments (microlites common). One oolitic glauconite pellet noted in sample from Section 1 (120 cm) and scattered radiolarian tests. Dark color may be pyrite. Ash is almost all clear glass with some feldspar. Silty clay is homogeneous except from the sandy and ash-rich patches and a few hardened pieces of silty clay. Intense drilling deformation.

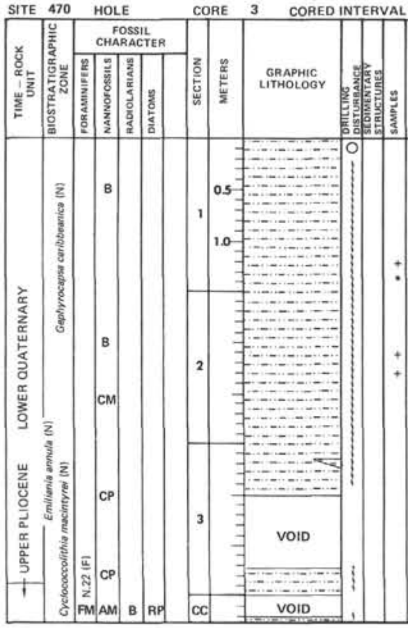
ORGANIC CARBON AND CARBONATE

	2-70	3-100
% Organic Carbon	–	0.23
% $CaCO_3$	10	3

SMEAR SLIDE SUMMARY

	1-120 (M)	5-57 (D)
TEXTURE:		
Sand	70	–
Silt	30	20
Clay	–	80
COMPOSITION:		
Quartz	15	4
Feldspar	10	10
Mica	3	TR
Heavy minerals	5	3
Clay	–	80
Volcanic glass	10	6
Glauconite	3	–
Pyrite	5	TR
Zeolite	TR	–
Calc. Nannofossils	–	3
Radiolarians	TR	TR
Sponge spicules	TR	–
Lithic fragments (volcanic)	44	–

SITE 470 HOLE CORE 3 CORED INTERVAL 19.0–28.5 m



LITHOLOGIC DESCRIPTION

Sandy ash patches

5Y 5/2 to 5GY 6/1

Sandy ash

Vitric ash patches

SILTY CLAY, light olive gray (5Y 5/2) to greenish gray (5GY 6/1) with scattered dark gray (N3) **SANDY ASH** patches and medium gray (N4) **VITRIC ASH** patches. Silty clay is homogeneous except for these minor lithologies as marked. Intense drilling deformation.

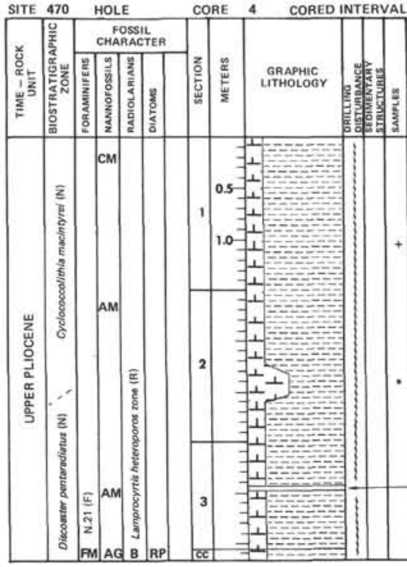
ORGANIC CARBON AND CARBONATE

	1-128	2-70	2-86
% Organic Carbon	0.23	–	–
% $CaCO_3$	11	3	4

SMEAR SLIDE SUMMARY

	1-140 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	20
Feldspar	2
Mica	1
Heavy minerals	1
Clay	60
Volcanic glass	5
Glauconite	TR
Carbonate unspec.	5
Foraminifers	1
Calc. Nannofossils	5

SITE 470 HOLE CORE 4 CORED INTERVAL 28.5–38.0 m



LITHOLOGIC DESCRIPTION

5GY 6/1

Nannofossil-rich interval 5Y 6/1

5GY 6/1

VOID Drilling fractures

NANNOFOSSIL CLAY, light olive gray (5Y 6/1) to greenish gray (5GY 6/1) with occasional light greenish gray (5G 8/1) mottles and scattered dark pyrite(?)-rich patches. Lighter colors reflect more nannofossil-rich sediment. Intense drilling deformation.

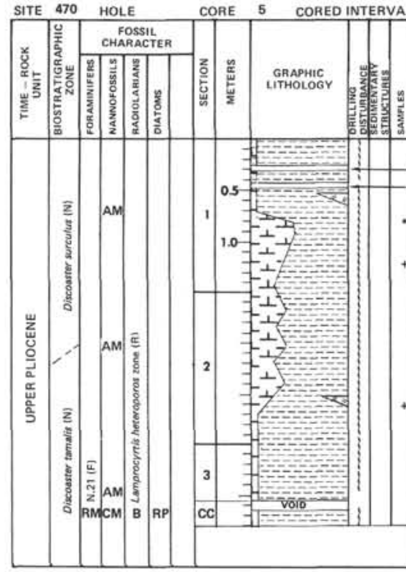
ORGANIC CARBON AND CARBONATE

	1-108
% Organic Carbon	–
% $CaCO_3$	16

SMEAR SLIDE SUMMARY

	2-93 (D)
TEXTURE:	
Sand	–
Silt	12
Clay	88
COMPOSITION:	
Quartz	TR
Feldspar	TR
Mica	TR
Heavy minerals	1
Clay	50
Volcanic glass	2
Carbonate unspec.	6
Foraminifers	1
Calc. Nannofossils	40

SITE 470 HOLE CORE 5 CORED INTERVAL 38.0–47.5 m



LITHOLOGIC DESCRIPTION

VOID

VOID

Mottled 5G 6/1 and 5G 5/1

CLAY AND NANNOFOSSIL CLAY, greenish gray (5G 5/1) to pale greenish gray (5G 6/1), lighter colors more nannofossil-rich sediment. Mottled nannofossil-rich intervals in base Section 1 – top of Section 2 deformed by drilling. Several scattered patches of brownish gray (5YR 5/1) **VITRIC ASH.** Dark gray pyrite(?)-rich streaks common near base of Section 1. Intense drilling deformation.

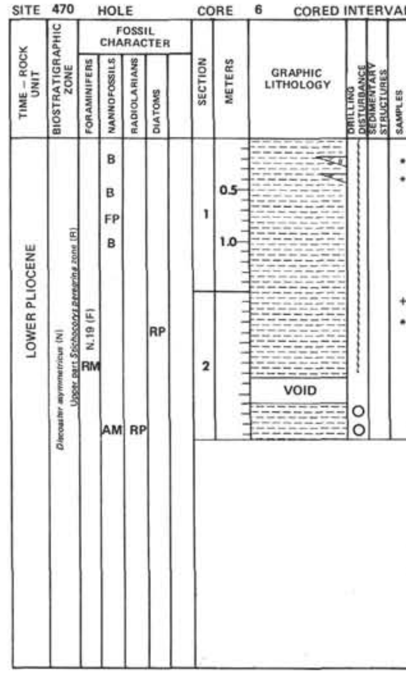
ORGANIC CARBON AND CARBONATE

	1-128	2-117
% Organic Carbon	–	0.33
% $CaCO_3$	27	14

SMEAR SLIDE SUMMARY

	1-85 (D)
TEXTURE:	
Sand	–
Silt	15
Clay	85
COMPOSITION:	
Quartz	5
Feldspar	1
Mica	1
Heavy minerals	TR
Clay	33
Foraminifers	10
Calc. Nannofossils	50

SITE 470 HOLE CORE 6 CORED INTERVAL 47.5–57.0 m



LITHOLOGIC DESCRIPTION

Calcareous claystone pieces

Calcareous claystone pieces

CLAY, dark greenish gray (5GY 4/1) with patches of light olive brown (5Y 5/6) **VITRIC ASH** near top of Section 1. Several pieces of semi-lithified calcareous claystone occur near base of Section 1 – top Section 2. Incipient carbonate cement in these pieces. Intense drilling deformation.

No Core-Catcher.

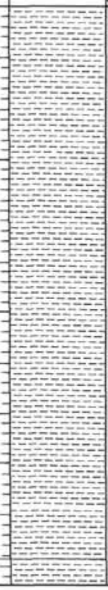
ORGANIC CARBON AND CARBONATE

	2-10
% Organic Carbon	–
% $CaCO_3$	27

SMEAR SLIDE SUMMARY

	1-45 (D)	1-24 (M)	2-30 (M) (Calcareous claystone)
TEXTURE:			
Sand	–	–	–
Silt	15	100	25
Clay	85	–	75
COMPOSITION:			
Quartz	5	2	TR
Feldspar	3	3	TR
Mica	TR	TR	–
Heavy minerals	2	TR	–
Clay	80	–	75
Volcanic glass	1	94	–
Glauconite	TR	–	–
Pyrite	1	1	5
Carbonate unspec.	5	–	20
Calc. Nannofossils	3	–	–
Diatoms	TR	–	–
Sponge spicules	TR	–	–
Plant debris	TR	–	–
Apatite	–	TR	–

SITE 470 HOLE CORE 7 CORED INTERVAL 57.0–66.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER PLIOCENE	N.19 (F); Mixed *Amaurolithus primus* to *Discoaster asymmetricus* (N); Upper part *Stichocorys peregrina* (R)	FM	AM, AM, AM	RP	RM	1, 2, 3, 4, CC	0.5, 1.0				+, +

LITHOLOGIC DESCRIPTION

CLAY, grayish olive (10Y 4/2), soupy and completely homogenized by drilling. Several lumps of semi-lithified clay and scattered foraminifers and dark organic(?) particles scattered throughout.

ORGANIC CARBON AND CARBONATE

	2-40	2-88
% Organic Carbon	0.16	–
% $CaCO_3$	17	11

SITE 470 HOLE CORE 8 CORED INTERVAL 66.5–76.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
UPPER MIOCENE	N.17 (F); *Discoaster quinqueramus* (N); Lower part *Stichocorys peregrina* (R); *Thalassiosira antiqua* (D)	FM	AM, B, B, CM	AM	AG	1, 2, 3, CC	0.5, 1.0				OG, +

Nannofossil-rich layer

LITHOLOGIC DESCRIPTION

CLAY changing to **DIATOMACEOUS SILTY CLAY** in Section 2, dark greenish gray (5GY 8/1) with abundant dark- and light-colored streaks formed by mixing during drilling. Section 1 contains common patches of light greenish gray (5G 8/1) **CLAYEY NANNOFOSSIL OOZE** and several patches of light olive gray (5Y 6/1) to greenish gray (5GY 6/1) **CLAYEY VITRIC ASH**. Layer of light greenish gray **CLAYEY NANNOFOSSIL OOZE** marks top Section 2. Lower contact is sharp but deformed by drilling. Foraminifers common in patch at 80–62 cm, Section 2.

ORGANIC CARBON AND CARBONATE

	2-80
% Organic Carbon	–
% $CaCO_3$	2

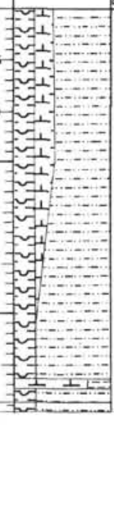
SMEAR SLIDE SUMMARY

	1-8 (D)	1-62 (M)	1-77 (M)	2-10 (M)	2-25 (D)
TEXTURE:					
Sand	–	–	–	–	–
Silt	15	60	10	10	45
Clay	85	40	90	90	55
COMPOSITION:					
Quartz	1	1	TR	3	5
Feldspar	1	2	TR	2	3
Mica	–	TR	–	TR	TR
Heavy minerals	–	TR	TR	TR	1
Clay	35	35	10	40	55
Volcanic glass	–	50	–	TR	2
Glauconite	–	TR	–	TR	–
Pyrite	1	1	1	1	2
Carbonate unspec.	6	1	4	–	1
Foraminifers	1	TR	2	TR	–
Calc. Nannofossils	50	10	80	50	–
Diatoms	2	TR	1	2	20
Radiolarians	TR	–	TR	TR	1
Sponge spicules	2	TR	1	2	7
Silicoflagellates	1	–	1	TR	3
Plant debris	–	–	–	–	TR

SITE 470 HOLE CORE 9 CORED INTERVAL 76.0–85.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
UPPER MIOCENE	N.17 (F) *Ommatartus antepenultimus* (R) *Discoaster neohamatus* (N)		CM			1	0.5, 1.0
						2	
						3	
		RM	CM	AG	AM	CC	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

Dark patch

5G 6/1

Deformed nannofossil-ooze layer

DIATOM-NANNOFOSSIL SILTY CLAY changing to **DIATOMACEOUS SILTY CLAY** in Section 2, greenish gray (5G 6/1) with grayish purple (5P 4/2) and moderate olive brown (5Y 4/4) streaks. Interbed of light greenish gray (5G 8/1) **CLAYEY NANNOFOSSIL OOZE** in Section 3 *is intensely deformed by drilling.*

ORGANIC CARBON AND CARBONATE

	2-80	2-90
% Organic Carbon	–	0.27
% $CaCO_3$	6	3

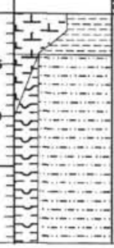
SMEAR SLIDE SUMMARY

	2-15 (D)	3-37 (D)
TEXTURE:		
Sand	–	–
Silt	30	30
Clay	70	70
COMPOSITION:		
Quartz	2	3
Feldspar	1	2
Mica	TR	TR
Heavy minerals	TR	–
Clay	50	65
Volcanic glass	1	TR
Glauconite	TR	–
Pyrite	2	1
Carbonate unspec.	2	4
Calc. Nannofossils	20	5
Diatoms	10	10
Radiolarians	2	5
Sponge spicules	7	3
Silicoflagellates	3	2

SITE 470 HOLE CORE 10 CORED INTERVAL 85.5–95.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
UPPER MIOCENE	N.16 (F) *Ommatartus antepenultimus* (R) *Discoaster neohamatus* (N) *Denticula hustedtii* "a" subzone (D)		AG			1	0.5, 1.0
		RP	CM	RG	RG	2	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

5Y 6/1

5G 6/1

Pumice lapilli

Pumice lapilli

NANNOFOSSIL CLAY, light olive gray (5Y 6/1) to light greenish gray (5G 8/1), changing to greenish gray (5G 6/1) **DIATOMACEOUS SILTY CLAY** in Section 1. Contact between two lithologies is gradational and mixed by drilling. Scattered gray pumice lapilli occur between 27–28 cm and 55–70 cm, Section 2. Grayish purple (5P 4/2) pyrite(?)-rich streaks common between 0–30 cm, 40–94 cm, Section 1 and 0–15 cm, Section 2.

No Core-Catcher.

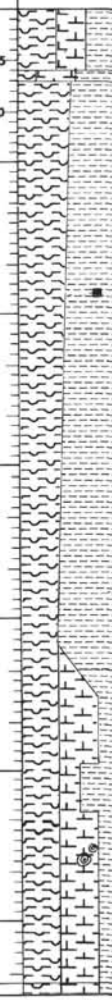
ORGANIC CARBON AND CARBONATE

	1-80	1-100
% Organic Carbon	–	0.59
% $CaCO_3$	11	11

SITE 470 HOLE CORE 11 CORED INTERVAL 95.0–104.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
UPPER MIOCENE	*Discoaster bellus* (N) *Denticula hustedtii – Denticula lauta* subzone "d" (D)				AG	1	0.5, 1.0
			CP			2	
						3	
						4	
	Discoaster hamatus (N) *Denticula hustedtii – Denticula lauta* subzone "c" (D)		AM		AG	5	
	N.16 (F) *Ommatartus antepenultimus* zone (R)		AM				
			CM			6	
			CM			7	
		FM	AG	CM	CM	CC	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

5G 6/1

10Y 6/2 Nannofossil-rich layer

Pumice lapilli

5G 6/1

5Y 6/1

Reduction aureoles

DIATOMACEOUS SILTY CLAY, greenish gray (5G 6/1) and pale olive (10Y 6/2) to light olive gray (5Y 6/1) **DIATOM-NANNOFOSSIL CLAY,** lighter colors indicate more nannofossil-rich sediment. Nannofossils common in top Section 1 and again Sections 5–7. Diatom-rich sediments predominate in base Section 1 and Sections 2–4. Pumice lapilli in Section 2 and grayish purple pyrite(?)-rich reduction(?) aureoles in nannofossil-rich sediments of Section 6. All contacts gradational. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

	1-80
% Organic Carbon	–
% $CaCO_3$	4

SMEAR SLIDE SUMMARY

	1-30 (D)	1-85 (D)	4-6 (D)	5-90 (D)
TEXTURE:				
Sand	–	–	–	–
Silt	40	45	41	30
Clay	60	55	59	70
COMPOSITION:				
Quartz	3	7	7	TR
Feldspar	2	3	3	TR
Mica	TR	TR	TR	TR
Heavy minerals	TR	TR	TR	–
Clay	20	25	20	10
Volcanic glass	2	TR	–	–
Glauconite	TR	TR	–	–
Pyrite	1	1	2	–
Carbonate unspec.	2	1	2	TR
Calc. Nannofossils	30	5	9	40
Diatoms	35	50	46	35
Radiolarians	3	3	5	5
Sponge spicules	2	2	2	–

SITE 470 HOLE CORE 12 CORED INTERVAL 104.5–114.0 m

TIME – ROCK UNIT: MIDDLE MIOCENE TO UPPER MIOCENE

BIOSTRATIGRAPHIC ZONE: *Discoaster hamatus* (N) *Denticula hustedtii – Denticula lauta* subzone "c" (D); *Ommatartus antepenultimus* zone (R); *Catinaster coalitus* or *Discoaster hamatus* (N)

FOSSIL CHARACTER (Nannofossils): AM, AM, AP, AP, FP, AM, CP, AM, CP; Core-catcher: RP FM CP

SECTION: 1 (VOID), 2, 3, 4, 5, 6, 7, 8, CC

Pumice fragment

5G 6/2

Dark ash(?) patch

Ash-rich patches

Scattered nannofossil-rich mottles

5G 5/2

Dark ash(?) patches

IW

DIATOMACEOUS SILTY CLAY, greenish gray (5G 6/2) to grayish green (5G 5/2), with light colored mottles of nannofossil-rich silty clay scattered through Sections 5–7. Dark gray ash-rich patches in Sections 3 and 7. Pumice fragment at top of core. Possible burrows between 65–75 cm, Section 6.

ORGANIC CARBON AND CARBONATE

	4-30	4-120
% Organic Carbon	–	0.30
% $CaCO_3$	7	6

SMEAR SLIDE SUMMARY

	3-106 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	5
Feldspar	3
Mica	TR
Heavy minrals	TR
Clay	65
Glauconite	TR
Pyrite	2
Calc. Nannofossils	5
Diatoms	15
Radiolarians	3
Sponge spicules	2
Silicoflagellates	TR

SITE 470 HOLE CORE 13 CORED INTERVAL 114.0–123.5 m

TIME – ROCK UNIT: MIDDLE MIOCENE

BIOSTRATIGRAPHIC ZONE: *Cannartus petterssoni* (R) *Denticula hustedtii – lauta* subzone "c" (D)

FOSSIL CHARACTER: AM, RP; Section 2: RM RP FM CP

SECTION: 1, 2

DIATOMACEOUS SILTY CLAY, greenish gray (5G 6/1) with scattered dark pyrite(?)-rich patches and small patches of light greenish gray (5G 8/1) nannofossil ooze. Intense drilling deformation.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-100
% Organic Carbon	–
% $CaCO_3$	3

SMEAR SLIDE SUMMARY

	1-90 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	5
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	75
Volcanic glass	TR
Pyrite	1
Carbonate unspec.	1
Diatoms	10
Radiolarians	3
Sponge spicules	2

SITE 470 HOLE CORE 14 CORED INTERVAL 123.5–133.0 m

TIME – ROCK UNIT: MIDDLE MIOCENE

BIOSTRATIGRAPHIC ZONE: *Coccolithus miopelagicus* (N) *Discoaster kugleri* (N); (R) *Denticula hustedtii – D. lauta* subzone "c" (D); N.11 or N.12 (F) *Cannartus petterssoni*

FOSSIL CHARACTER (Nannofossils): AM, CM, FM, B; Core-catcher: RM AM CG AM

SECTION: 1, 2, CC

OG

5G 6/1

5G 6/1

Sharp color change 5GY 8/1

DIATOMACEOUS SILTY CLAY, greenish gray (5G 6/1) with purple gray (5P 4/2) pyrite(?)-rich streaks and patches and a small patch of vitric ash. Clay changes abruptly abruptly to light greenish gray (5GY 8/1) **DIATOM-NANNOFOSSIL OOZE** at 100 cm, Section 2. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

	1-30	2-80
% Organic Carbon	–	0.51
% $CaCO_3$	12	3

SMEAR SLIDE SUMMARY

	1-30 (D)
TEXTURE:	
Sand	–
Silt	35
Clay	65
COMPOSITION:	
Quartz	5
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	55
Volcanic glass	TR
Pyrite	2
Carbonate unspec.	TR
Foraminifers	TR
Calc. Nannofossils	10
Diatoms	15
Radiolarians	5
Sponge spicules	TR
Silicoflagellates	5

SITE 470 HOLE CORE 15 CORED INTERVAL 133.0–142.5 m

TIME – ROCK UNIT: MIDDLE MIOCENE

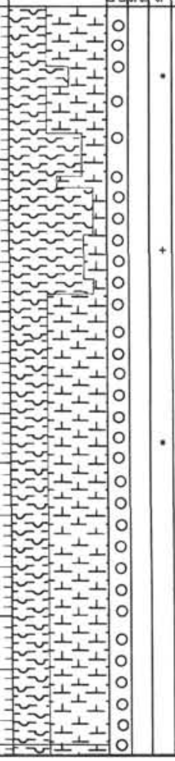
BIOSTRATIGRAPHIC ZONE: N.11 or N.12 (F); *Denticula hustedtii – Denticula lauta* subzone "b" (D); *Coccolithus miopelagicus* (N); *Cannartus petterssoni* zone (R)

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): AM; CM; AM; CC: RM AM AM AM

SECTION: 1, 2, 3, 4, 5, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 6/1
5Y 4/4
5Y 6/1
5Y 4/4
5Y 6/1
5Y 4/4
5Y 4/4
5Y 6/1

Greenish gray (5Y 6/1) to medium gray (N5) **DIATOM-NANNOFOSSIL OOZE** and dusky yellow (5Y 6/4) to moderate olive brown (5Y 4/4) **NANNOFOSSIL-DIATOMACEOUS OOZE** thoroughly mixed and deformed by drilling. Scattered dark pyrite(?)-rich patches throughout.

ORGANIC CARBON AND CARBONATE

	2-90
% Organic Carbon	–
% $CaCO_3$	30

SMEAR SLIDE SUMMARY

	1-70 (D)	3-135 (D)
TEXTURE:		
Sand	–	–
Silt	70	25
Clay	30	75
COMPOSITION:		
Quartz	TR	–
Feldspar	TR	–
Mica	TR	–
Heavy minerals	TR	–
Clay	10	–
Pyrite	1	–
Carbonate unspec.	1	–
Calc. Nannofossils	20	75
Diatoms	60	20
Radiolarians	3	2
Sponge spicules	TR	–
Silicoflagellates	5	3

SITE 470 HOLE CORE 16 CORED INTERVAL 142.5–152.0 m

TIME – ROCK UNIT: MIDDLE MIOCENE

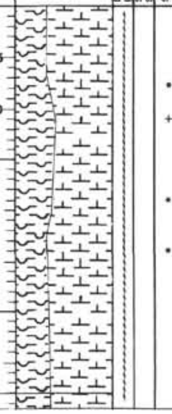
BIOSTRATIGRAPHIC ZONE: *Dorcadospyris alata* (R); *Coccolithus miopelagicus* (N); *D. hustedtii–D. lauta* subzone "b" (D); N.11 or N.12 (F); *Denticula hustedtii–Denticula lauta* subzone "a" (D)

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): AM; CC: RM AM AM AG

SECTION: 1, 2, 3, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5G 8/1
5G 5/2
5G 8/1

DIATOM-NANNOFOSSIL OOZE, greenish gray (5G 8/1) and light greenish gray (5G 6/1) to grayish green (5G 5/2), lighter colors indicate more nannofossil-rich sediment. Scattered dark pyrite(?)-rich patches and streaks. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

	1-110
% Organic Carbon	0.25
% $CaCO_3$	46

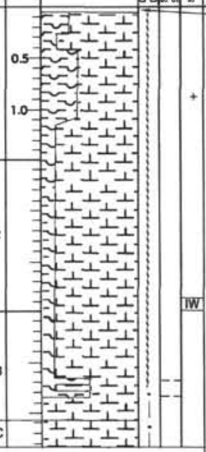
SMEAR SLIDE SUMMARY

	1-85 (D)	2-46 (D)	2-95 (D)
TEXTURE:			
Sand	–	–	–
Silt	10	23	9
Clay	90	77	91
COMPOSITION:			
Quartz	–	TR	TR
Feldspar	–	TR	TR
Mica	TR	–	TR
Heavy minerals	1	6	5
Glauconite	TR	–	–
Pyrite	–	TR	–
Calc. Nannofossils	72	71	86
Diatoms	20	18	8
Radiolarians	5	3	1
Sponge spicules	1	2	–
Silicoflagellates	1	TR	TR

SITE 470 HOLE CORE 17 CORED INTERVAL 152.0–161.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
MIDDLE MIOCENE	*Coccolithus miopelagicus* (N); *Dorcadospyris alata* (R); *Denticula hustedtii* – *Denticula lauta* subzone "a" (D)		AM		AG	1, 2
	N.10 (F); *Denticula lauta* (D)				CM	3
		RM	AM	FM	FM	CC

GRAPHIC LITHOLOGY



VOID

Mottled 5G 6/1 and 5G 8/1

5G 7/1

IW

Two dark layers

5G 8/1

LITHOLOGIC DESCRIPTION

DIATOM-NANNOFOSSIL OOZE, greenish gray (5G 6/1) to medium greenish gray (5G 7/1) with scattered pyrite(?)-rich patches and streaks. Light greenish gray (5G 8/1) **NANNOFOSSIL OOZE** occurs below two greenish gray diatom(?)-rich layers at 70–80 cm Section 3. *Nannofossil* ooze is also mixed by drilling with more diatom-rich sediment in Section 1. Drilling deformation is intense above 70 cm, Section 3; sediment is firm and less deformed below this.

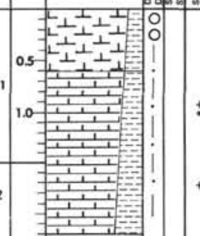
ORGANIC CARBON AND CARBONATE

	1-90
% Organic Carbon	–
% $CaCO_3$	66

SITE 470 HOLE CORE 18 CORED INTERVAL 161.5–168.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
MIDDLE MIOCENE	*Sphenolithus heteromorphus* (N); N.9 (F)		AM			1
			AM			1
		FM	AG	B	B	2

GRAPHIC LITHOLOGY



5G 8/1

5G 6/1

LITHOLOGIC DESCRIPTION

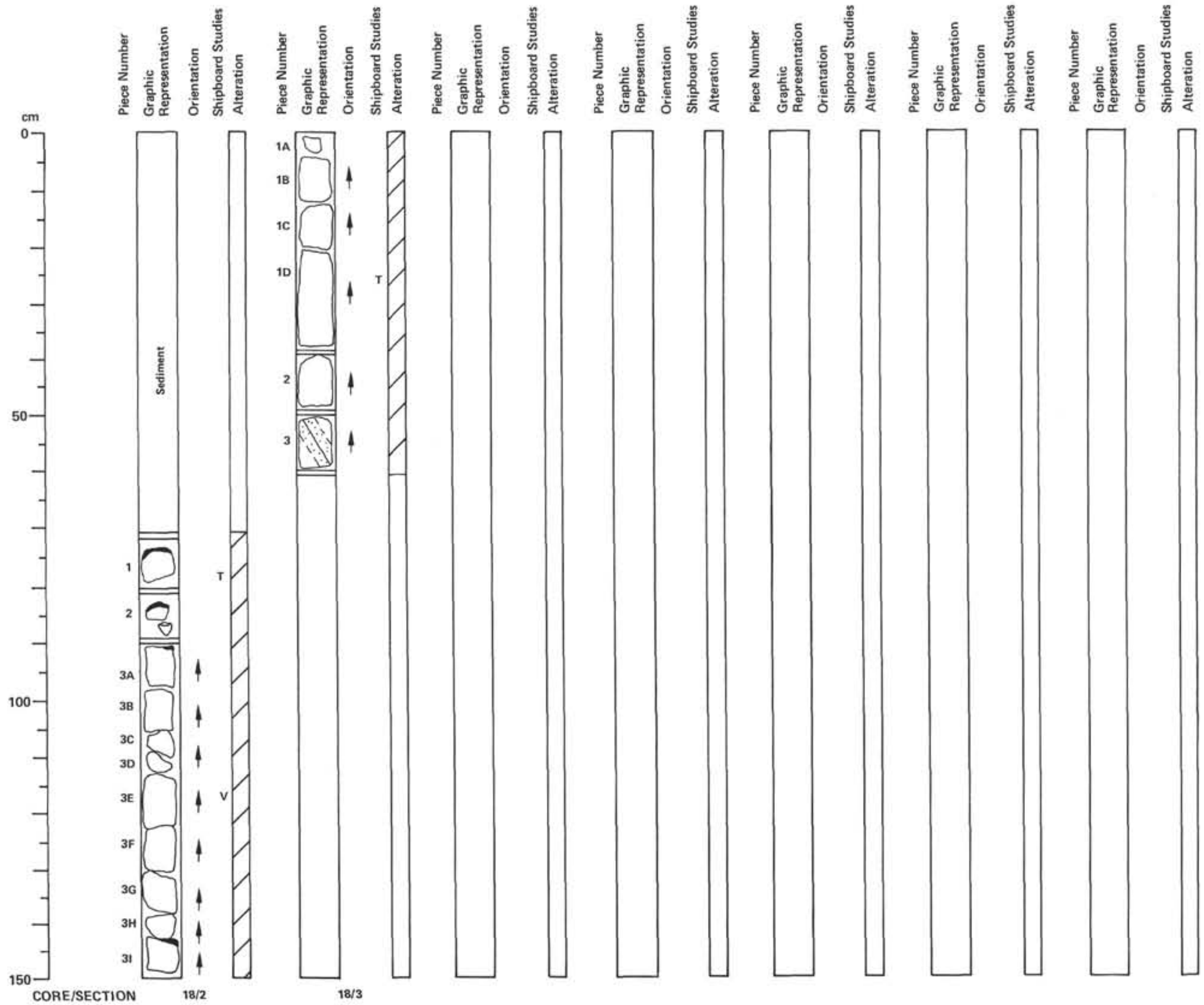
CLAYEY NANNOFOSSIL OOZE AND CHALK, light greenish gray (5G 8/1) to greenish gray (5G 6/1), slightly mottled with a few small pyrite-rich patches. Sediment becomes more firm gradually down-core; ooze-chalk transition at about 63 cm, Section 1. Basalt occurs below chalk at 72 cm, Section 2. The nannofossil-chalk immediately overlying the basalt contains scattered dolomite rhombs, pyrite crystals and manganese mineralization.

ORGANIC CARBON AND CARBONATE

	1-94	2-21
% Organic Carbon	–	0.11
% $CaCO_3$	77	71

SMEAR SLIDE SUMMARY

	1-105 (D)
TEXTURE:	
Sand	–
Silt	10
Clay	90
COMPOSITION:	
Quartz	–
Feldspar	–
Mica	TR
Heavy minerals	1
Clay	20
Foraminifers	1
Calc. Nannofossils	76
Sponge spicules	TR
Dolomite	3



SITE 470, CORE 18, SECTIONS 2–3, 162.7–165.1 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – medium dark gray, aphyric, moderately altered, and fractured. Pieces 1, 2, 3A, and 3I in Section 2 have glassy margins; slight increase in grain size away from glass. Calcite fills some fractures; yellowish gray alteration rind surrounds many fractures.

Thin Section Descriptions

Altered Olivine-Plagioclase Basalt – Section 2, Piece 1, 75–78 cm
Texture: porphyritic with subvariolitic groundmass
Phenocrysts: olivine (completely serpentinized), 1%, 0.02–0.3 mm, euhedral; plagioclase, 3%, 0.2–1.0 mm, euhedral; spinel, TR, subhedral, brownish
Groundmass: plagioclase, 30%, 0.01–0.6 mm, skeletal needles; clinopyroxene, 30%, feathery; mesostasis, 25%; opaques, 7%
Vesicles: 5%, 0.2–0.4 mm, oval
Alteration: olivine crystals completely serpentinized; calcite and brownish green clay fill vesicles; calcite fills cracks.

Altered Olivine-Plagioclase Basalt – Section 3, Piece 1D, 25–27 cm
Texture: glomeroporphyritic with intergranular to intersertal groundmass
Phenocrysts: olivine (completely replaced by clay and calcite), 2%, 0.3–0.5 mm, euhedral; plagioclase, 5%, 0.3–1.0 mm, euhedral
Groundmass: plagioclase, 30%, 0.05–0.2 mm, skeletal, prismatic; clinopyroxene, 40%, 0.01–0.2 mm, skeletal, feathery to equant; opaques, 10%; mesostasis, 10%
Vesicles: 3%, 0.2–0.4 mm, oval
Alteration: olivine serpentinized and replaced by calcite; calcite fills fractures and some vesicles; reddish brown clay fills some vesicles.

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 3E, 114 cm	–	5.89	–	–

SITE 470 HOLE A CORE 1 CORED INTERVAL 47.5–57.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
UPPER MIOCENE OR LOWER PLIOCENE	*Amaurolithus primus* to *Amaurolithus tricorniculatus* (N)	FM	AM, AM, AM, AM	QUATERNARY (R); B	FP	1, 2, 3, 4, CC	0.5, 1.0			IW	+	

5G 5/1

5G 6/1

5G 5/1

Distinct color change

5G 6/1

5G 5/1

CLAY AND NANNOFOSSIL CLAY, mottled greenish gray (5G 6/1) and moderate greenish gray (5G 5/1), lighter colors indicate more nannofossil-rich sediment (e.g. Section 2 and base Section 3). Scattered dark pyrite(?)-rich patches and streaks throughout. Patch of dark gray **VITRIC ASH** in Section 2.

ORGANIC CARBON AND CARBONATE

	1-78
% Organic Carbon	0.25
% $CaCO_3$	7

SITE 470 HOLE A CORE 2 CORED INTERVAL 57.0–66.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
UPPER MIOCENE	*Discoaster quinqueramus* (N)	RM	AM	? *S. peregrina* (lower) to *O. penultimus* (R)	RM	1, 2	0.5, 1.0	VOID				

NANNOFOSSIL CLAY, grayish green (5G 5/2) to grayish olive (10Y 4/2), mottled and intensely deformed by drilling. Slightly silty near top of Section 1. Scattered patches of **VITRIC ASH** as marked.

SITE 470 HOLE A CORE 3 CORED INTERVAL 66.5–76.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
UPPER MIOCENE	*Thalassiosira antiqua* (D); *Ommatartus penultimus* or lower *S. peregrina* zone (R); *Discoaster quinqueramus* (N)	FM	CM, AM, AM, B, B, CM, AM	CM	RM, AG	1, 2, 3, 4, 5, CC	0.5, 1.0				*, *, +	

Mixed 5Y 5/1 and 5Y 8/1

5Y 5/1

5Y 8/1 Nannofossil-rich interval

5Y 5/1

5Y 4/1

5Y 5/1

NANNOFOSSIL CLAY, medium greenish gray (5Y 5/1) to light greenish gray (5Y 8/1) with dark greenish gray (5Y 4/1) mottles. Intense mixing and deformation of sediment by drilling. Patch of **VITRIC ASH** base Section 4. Scattered pyrite-rich streaks and patches throughout.

ORGANIC CARBON AND CARBONATE

	2-89
% Organic Carbon	0.27
% $CaCO_3$	3

SMEAR SLIDE SUMMARY

	1-3 (M)	2-85 (D)
TEXTURE:		
Sand	–	–
Silt	8	8
Clay	92	92
COMPOSITION:		
Quartz	2	3
Feldspar	TR	–
Mica	TR	1
Heavy minrals	TR	1
Clay	50	70
Volcanic glass	TR	5
Glauconite	–	TR
Zeolite	–	TR
Carbonate unspec.	3	–
Foraminifers	–	TR
Calc. Nannofossils	44	10
Diatoms	2	7
Radiolarians	1	2
Sponge spicules	–	1
Dolomite	–	TR

SITE 470 HOLE A CORE 4 CORED INTERVAL 76.0–85.5 m

TIME – ROCK UNIT: UPPER MIOCENE

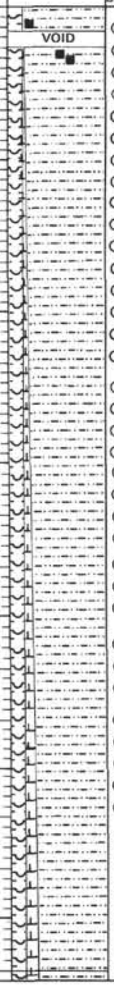
BIOSTRATIGRAPHIC ZONE: *Discoaster neorectus* (N); *Ommatartus antepenultimus* or *Ommatartus penultimus* (R) | *Thalassiosira antiqua* (R); *Discoaster berggreni* (N)

FOSSIL CHARACTER (Foraminifers / Nannofossils / Radiolarians / Diatoms): AM; AM; CM; CM; AM; FM CP AG

SECTION: 1, 2, 3, 4, 5, 6, 7, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES: IW

LITHOLOGIC DESCRIPTION

Volcanic rock fragment

Volcanic rock fragments

NANNOFOSSIL-DIATOMACEOUS SILTY CLAY, greenish gray (5G 6/1) to dark greenish gray (5G 4/1) with several dusky yellow green (5GY 5/2) mottles indicating more nannofossil-rich sediment. Intense mixing and deformation caused by drilling. Subangular volcanic rock fragment at 23 cm, Section 1 and two rounded fragments of the same volcanic rock type at 40 cm, Section 1.

ORGANIC CARBON AND CARBONATE

	6-141
% Organic Carbon	–
% $CaCO_3$	13

SMEAR SLIDE SUMMARY

	1-114 (D)
TEXTURE:	
Sand	–
Silt	30
Clay	70
COMPOSITION:	
Quartz	3
Feldspar	2
Heavy minerals	TR
Clay	62
Pyrite	1
Carbonate unspec.	3
Calc. Nannofossils	7
Diatoms	11
Radiolarians	4
Sponge spicules	3

SITE 470 HOLE A CORE 5 CORED INTERVAL 85.5–95.0 m

TIME – ROCK UNIT: UPPER MIOCENE

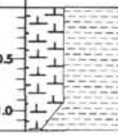
BIOSTRATIGRAPHIC ZONE: *Discoaster bellus* (N); *Ommatartus antepenultimus* (R); *Denticula hustedtii* subzone "a" (D)

FOSSIL CHARACTER (Foraminifers / Nannofossils / Radiolarians / Diatoms): AM; AM; AM; AM; FM AM FP AG

SECTION: 1

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

Mottled 5G 6/1 and 5G 8/1

NANNOFOSSIL CLAY, greenish gray (5G 6/1) and light greenish gray (5G 8/1), lighter colors indicate more nannofossil-rich sediment. Scattered pyrite-rich streaks and patches. Intense drilling deformation.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-90	1-115
% Organic Carbon	–	0.33
% $CaCO_3$	41	14

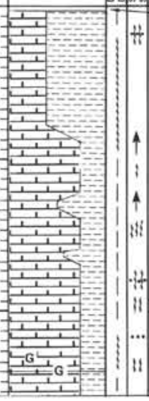
SMEAR SLIDE SUMMARY

	1-87 (D)
TEXTURE:	
Sand	–
Silt	5
Clay	95
COMPOSITION:	
Quartz	2
Heavy minerals	TR
Clay	40
Glauconite	TR
Carbonate unspec.	3
Foraminifers	TR
Calc. Nannofossils	40
Diatoms	7
Radiolarians	7
Sponge spicules	1
Silicoflagellates	TR

SITE 470 HOLE A CORE 6 CORED INTERVAL 161.5–166.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
MIDDLE MIOCENE	N.9 (F) / *Dorcadospyris alata*? (R) / *Sphenolithus heteromorphus* (N) / *Coccolithus miopelagicus* (N)	FM	AM, AM, AM	B	B	1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



VOID

5G 6/1

5GY 8/1

5G 6/1

5GY 8/1

5G 6/1

5GY 8/1

Glauconite
Glauconite
Dolomite

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK AND CLAYEY NANNOFOSSIL CHALK, light greenish gray (5GY 8/1) to greenish gray (5G 6/1), lighter colors indicate more nannofossil-rich sediments, zones of moderate to intense bioturbation and some lenticular bedding. Base of Core-Catcher is dolomitic(?) with scattered dolomitic rhombs in nannofossil chalk.

ORGANIC CARBON AND CARBONATE

	1-102
% Organic Carbon	–
% $CaCO_3$	37

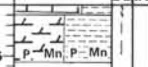
SMEAR SLIDE SUMMARY

	1-86 (D)	3-30 (D)	CC-21 (D)
TEXTURE:			
Sand	–	–	–
Silt	5	2	2
Clay	95	98	98
COMPOSITION:			
Quartz	2	TR	TR
Feldspar	1	–	TR
Mica	TR	2	2
Clay	11	–	3
Volcanic glass	TR	TR	TR
Pyrite	3	TR	2
Foraminifers	1	2	2
Calc. Nannofossils	75	91	76
Diatoms	TR	TR	–
Sponge spicules	2	–	–
Dolomite(?)	5	5	15

SITE 470 HOLE A CORE 7 CORED INTERVAL 166.5–171.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER MIDDLE MIOCENE	*Sphenolithus heteromorphus* (N)		AM B RP			1, 2, 3	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



BASALT

5Y 7/2

10Y 6/2

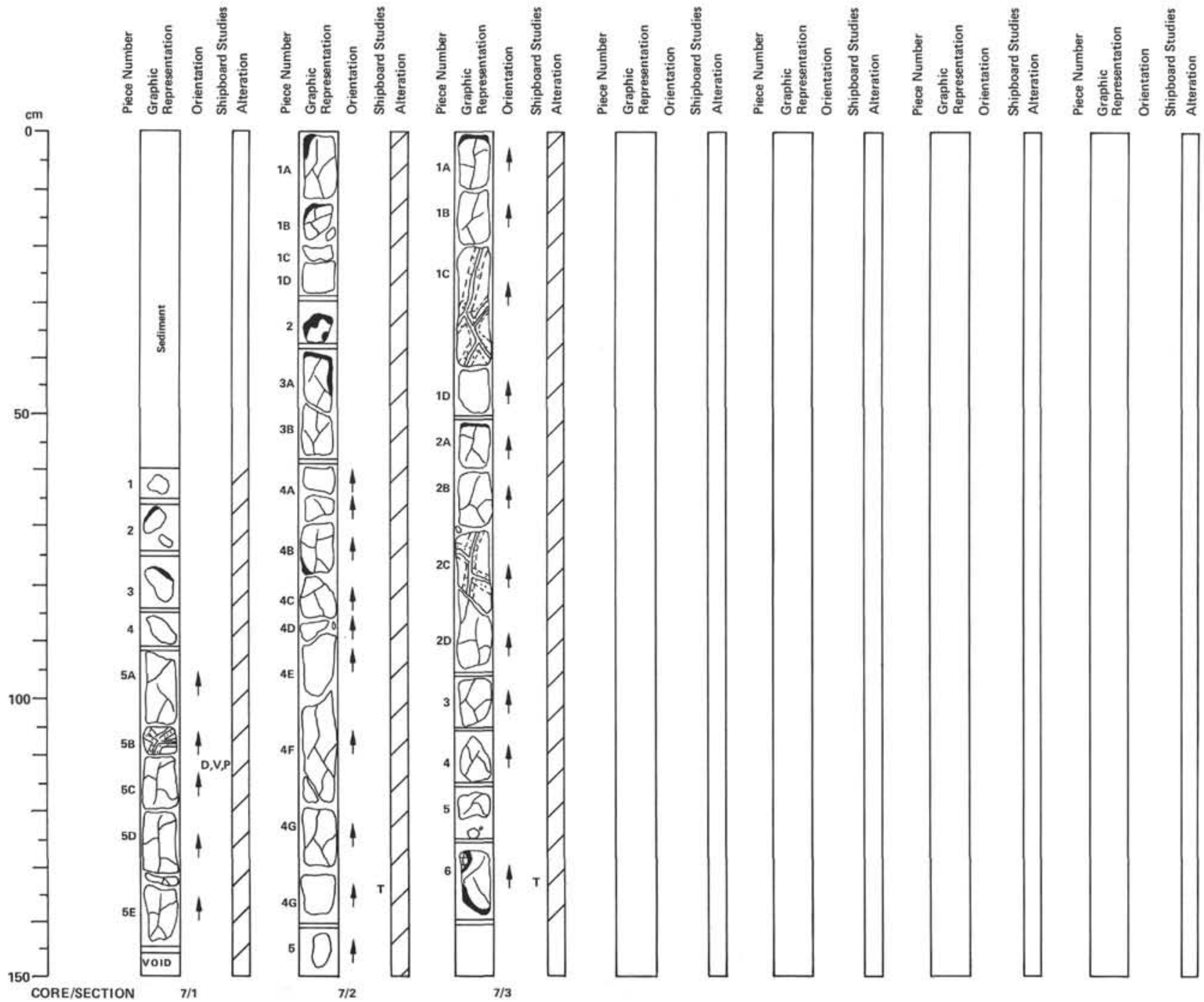
Pyrite(?) and manganese(?) mineralization

LITHOLOGIC DESCRIPTION

DOLOMITIC CLAYSTONE, pale olive (10Y 6/2), homogeneous except for small patches of dark gray (N3) to light olive brown (5Y 5/6) pyrite(?) and manganese(?) mineralization just above contact with underlying basalt. Top of core contains thin interval of yellowish gray (5Y 7/2) **CLAYEY NANNOFOSSIL CHALK.** Chalk contains several pyrite/manganese-rich patches.

SMEAR SLIDE SUMMARY

	1-2 (D)	1-44 (D)
TEXTURE:		
Sand	–	–
Silt	15	50
Clay	85	50
COMPOSITION:		
Quartz	1	TR
Feldspar	–	TR
Mica	TR	1
Heavy minerals	–	TR
Clay	10	51
Volcanic glass	1	5
Pyrite	TR	1
Calc. Nannofossils	83	–
Sponge spicules	TR	–
Dolomite(?)	15	49



HOLE 470A, CORE 7, SECTIONS 1–3, 167.1–170.9 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPE – LIMESTONE

Macroscopic Descriptions

Basalt – medium dark gray, aphyric to porphyritic, moderately altered and fractured. Grain size increases slightly down core in Section 1. Altered olivine phenocrysts scattered throughout. Glassy margins occur in pieces of all three sections as marked. In these, glass grades to brownish aphanitic basalt then to fine-grained basalt. Calcite and clay fill some fractures; common brownish gray alteration rind surrounds fractures.

Limestone – Piece 6 in Section 3 has a fragment of light greenish gray (5G 8/1), crystalline limestone included in the basalt. Contact between the two lithologies is sharp, separated by the glassy margin of the basalt.

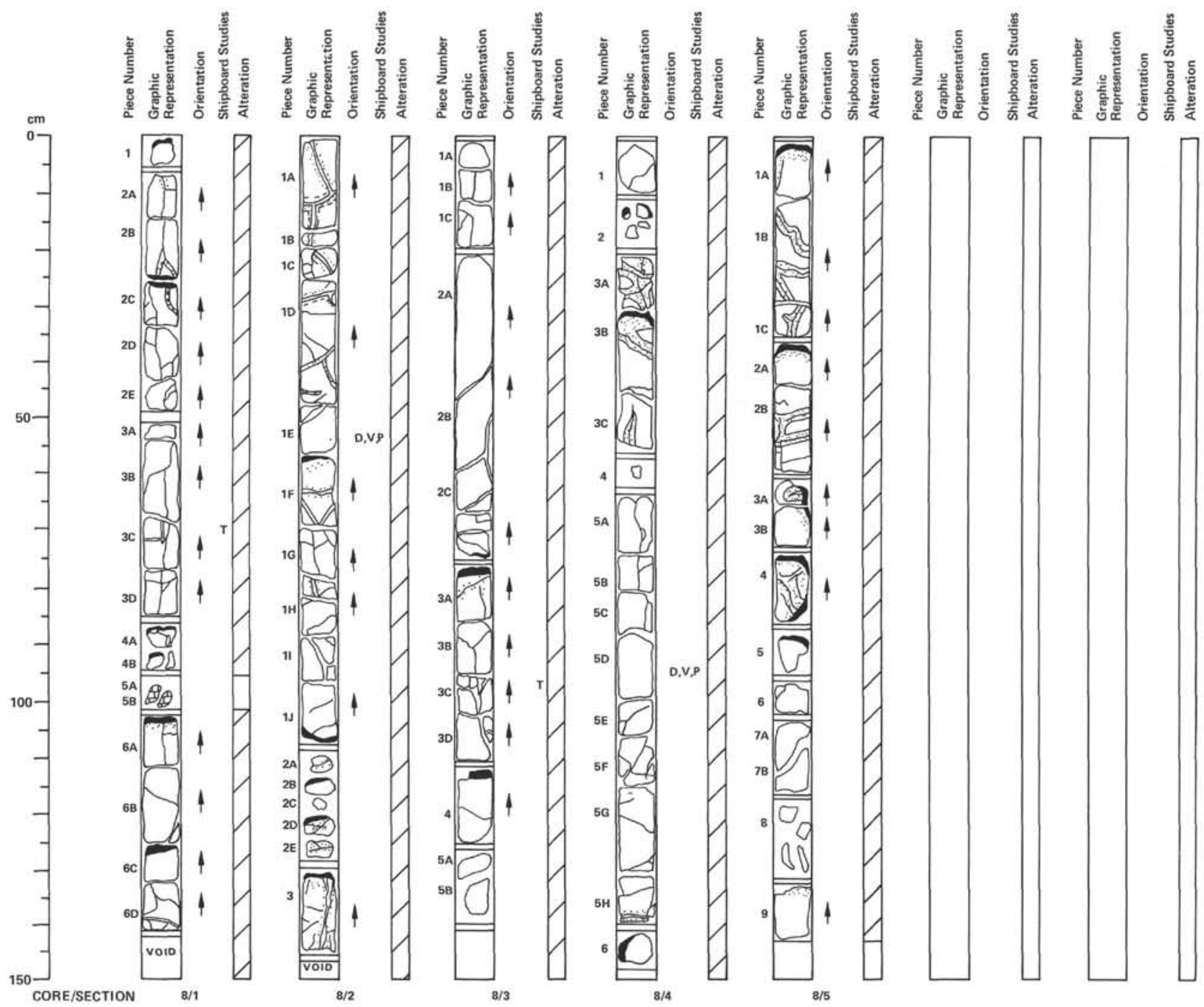
Thin Section Descriptions

Olivine-Plagioclase Basalte – Section 2, Piece 4H, 133–134 cm
Texture: porphyritic with intergranular to subvariolitic groundmass
Phenocrysts: olivine (partially or completely altered), 4%, 0.5–1.0 mm, euhedral; plagioclase, 4%, 0.5–2.0 mm, euhedral to subhedral; spinel, TR, 0.1 mm, euhedral
Groundmass: plagioclase, 40%, 0.05–0.3 mm, acicular prisms; clinopyroxene, 42%, 0.1–0.5 mm, anhedral; opaques, 6%, needles
Vesicles: 2%, 0.2–0.3 mm, circular
Alteration: olivine crystals partially or completely replaced by brownish clay; clacite and brownish clay fill cracks and some vesicles

Olivine-Plagioclase Basalt (next to glassy margin) – Section 3, Piece 6, 133–134 cm
Texture: porphyritic with subvariolitic groundmass
Phenocrysts: plagioclase, 2%, 0.5 mm, euhedral; olivine (altered), TR, 0.5 mm, euhedral
Groundmass: plagioclase, 40%, 0.05–0.1 mm, skeletal-hollow, acicular; clinopyroxene, 40%, 0.01–0.1 mm, feathery, dendritic; olivine, 4%, 0.01–0.05 mm, euhedral, equant; opaques, 5%; mesostasis, 9%
Vesicles: TR, 0.2 mm, circular
Alteration: olivine phenocrysts replaced by brown clay; calcite and clay fill some cracks and vesicles

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 5C, 110 cm	2.83	5.35		7



HOLE 470A, CORE 8, SECTIONS 1–5, 171.0–178.4 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPE – LIMESTONE

Macroscopic Description

Basalt – medium dark gray, aphyric to porphyritic, moderately altered, and fractured. Many pieces have glassy margins (as marked), with grain size increasing away from glass. Olivine phenocrysts altered to green clay scattered throughout core. Some fractures filled with calcite or clay; common brownish gray alteration rind surrounds fractures.

Limestone – Pieces 5A–B in Section 1 are light greenish gray crystalline limestone. No sedimentary structures. Contact with basalt not recovered.

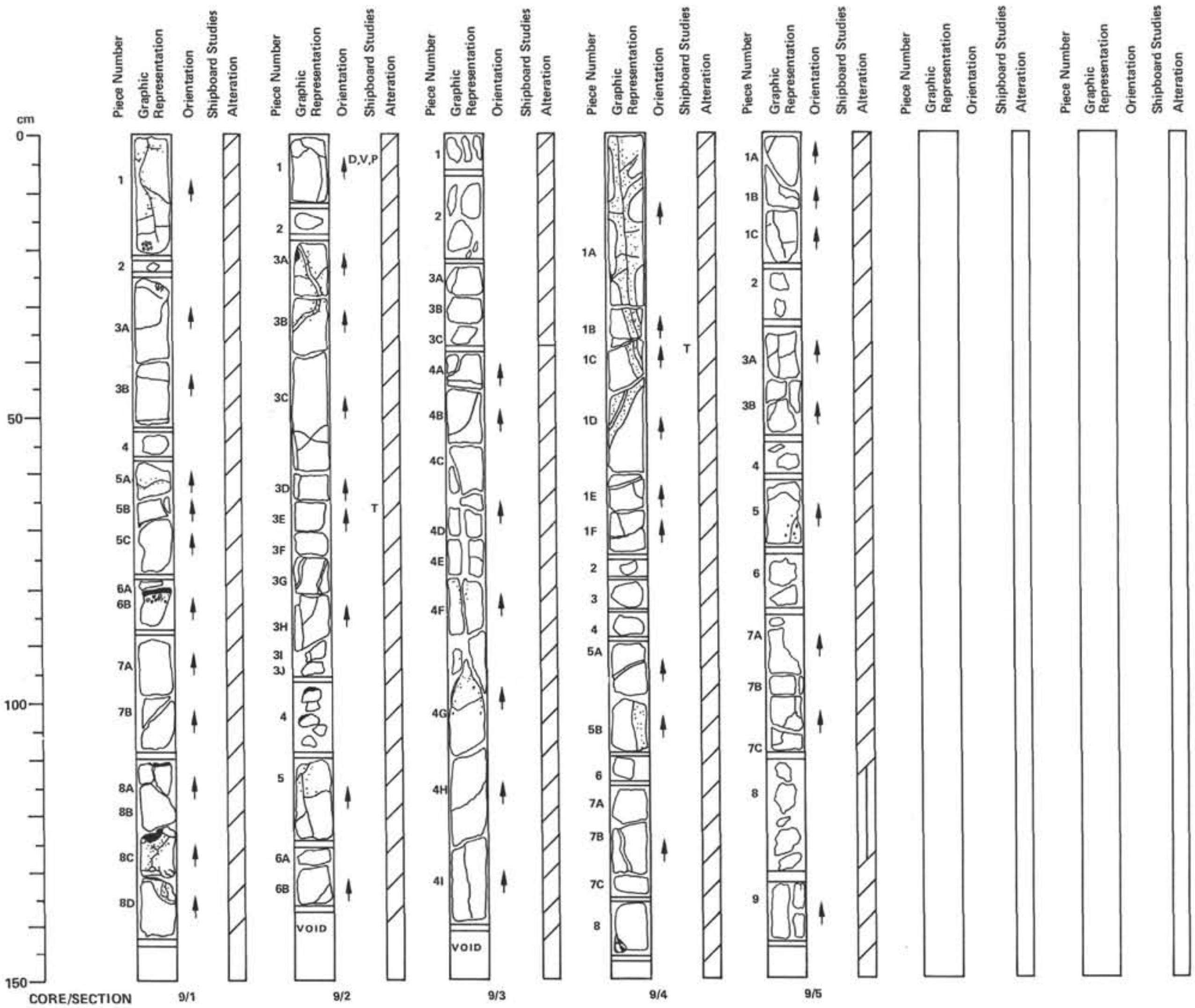
Thin Section Descriptions

Phyric Plagioclase Basalt – Section 1, Piece 3C, 69–71 cm
Texture: glomeroporphyritic with intergranular groundmass
Phenocrysts: plagioclase, 2%, 0.3–1.0 mm, euhedral
Groundmass: plagioclase, 42%, 0.03–0.2 mm, skeletal-hollow crystals; clinopyroxene, 42%, 0.05–0.2 mm, feathery, dendritic; olivine, 3%, 0.05–1.0 mm, anhedral, equant; opaques, 10%, 0.01–0.05 mm, skeletal, equant
Vesicles: 1%, 0.2 mm, circular
Alteration: calcite and clays fill cracks and some vesicles; olivine crystals partially replaced by clay

Olivine-Plagioclase Basalt – Section 3, Piece 3C, 95–98 cm
Texture: porphyritic with intergranular to intersertal groundmass
Phenocrysts: plagioclase, 2%, 0.5–1 mm, euhedral; olivine (altered), 1%, 1 mm, euhedral
Groundmass: plagioclase, 38%, 0.05–0.3 mm, skeletal; clinopyroxene, 40%, 0.03–0.3 mm, skeletal, feathery; olivine, 2%, 0.05–0.2 mm, anhedral, equant; opaques, 5%; mesostasis, 9%
Vesicles: 3%, 0.2–0.4 mm, circular
Alteration: calcite and clays fill cracks and some vesicles; olivine crystals partially replaced by clay

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 1E, 54 cm	2.88	5.37	–	4
Section 4, Piece 5D, 93 cm	2.92	5.88	–	3



HOLE 470A, CORE 9, SECTIONS 1–5, 180.5–188.0 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – medium dark gray, aphyric to porphyritic, moderately, altered and fractured. Glassy margins common (as marked); grain size increases away from glass. Grain size increase slightly from fine- to medium-grained basalt in Section 3 between 0–37 cm. Piece 4 in that section is medium-grained. In Section 4 Pieces 2–4 are fine-grained, remaining basalt is medium-grained. Grain size is variable in other sections. Altered olivine phenocrysts about 1 mm across are scattered throughout. Vesicles are common in some pieces (Section 1, Pieces 1 and 3A; Section 3, scattered). Calcite and clay fill some fractures; common brownish gray alteration rind surrounds fractures. Calcite also fills some vesicles in Section 3. Fragments comprising Piece 8 in Section 5 are strongly altered; brownish color suggests clays.

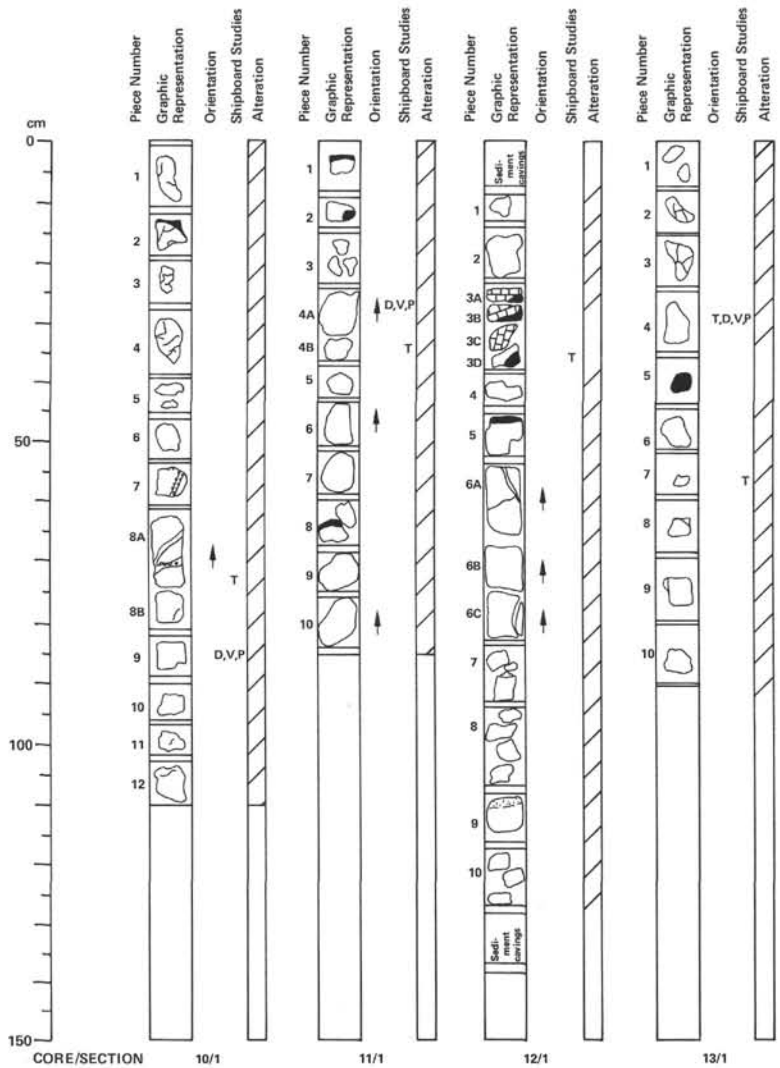
Thin Section Descriptions

Phyric Olivine-Plagioclase Basalt – Section 2, Piece 3E, 65–68 cm
Texture: porphyritic with intergranular to intersertal groundmass
Phenocrysts: plagioclase, 2%, 0.5–1 mm, euhedral; olivine (partly altered), 1%, 0.5 mm, euhedral
Groundmass: plagioclase, 34%, 0.05–0.3 mm, skeletal; clinopyroxene, 35%, 0.03–0.2 mm, skeletal, feathery, dendritic; olivine, 3%, 0.05–0.1 mm, euhedral, equant to slender prisms; opaques, 7%; mesostasis, 15%
Vesicles: 3%, 0.2–0.4 mm, circular
Alteration: clay occurs in vesicles, cracks and in interstices between plagioclase and pyroxene crystals; olivine altered to clays

Phyric Olivine-Plagioclase Basalt – Section 4, Piece 1B, 34–36 cm
Texture: glomeroporphyritic with intergranular to subophitic groundmass
Phenocrysts: plagioclase, 3%, 0.5–2 mm, euhedral; olivine (partly altered), 1%, 0.5–1 mm, euhedral
Groundmass: plagioclase, 41%, 0.1–0.5 mm, slender laths; clinopyroxene, 40%, 0.05–1 mm, anhedral; olivine, 5%, 0.03–0.2 mm, prismatic, anhedral, equant; opaques, 8%, 0.05–0.1 mm
Vesicles: 2%, 0.2–0.4 mm, circular
Alteration: calcite fills cracks; clay replaces olivine and mesostasis between plagioclase and pyroxene crystals

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 1, 4 cm	2.89	5.26	–	3



HOLE 470A, CORE 10, SECTION 1, 189.5–190.6 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – medium dark gray, moderately altered and fractured. Phyric, fine- to medium-grained; Pieces 6–9 and 12 are distinctly coarser grained and most similar to the basalts in Sections 3–5, Core 9. Pieces 10–11 are aphyric basalt. Calcite fills fractures in Pieces 7 and 8A. Piece 2 has glassy margin.

Thin Section Description

Phyric Olivine-Plagioclase Basalt – Piece 8B, 75–80 cm

Texture: glomeroporphyritic with intergranular to subophitic groundmass

Phenocrysts: plagioclase, 3%, 0.5–1.5 mm, euhedral; olivine (partly altered), TR, 0.5–1 mm, euhedral

Groundmass: plagioclase, 41%, 0.1–0.5 mm, slender laths; clinopyroxene, 43%, 0.05–1 mm, anhedral; olivine, 4%, 0.03–0.2 mm, anhedral, prismatic, equant; opaques, 6%, 0.05–0.1 mm

Vesicles: 3%, 0.2–0.4 mm, circular

Alteration: clay fills vesicles and replaces olivine phenocrysts and mesostasis between plagioclase and pyroxene grains

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 9, 86 cm	2.87	6.00	–	5

HOLE 470A, CORE 11, SECTION 1, 194.5–195.4 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – medium dark gray, fine-grained and aphyric, moderately altered and fractured. Pieces 1, 2, and 8 have glassy margins with progressive increase in grain size away from margins.

Thin Section Description

Phyric Plagioclase Basalt – Piece 4B, 34–37 cm

Phenocrysts: plagioclase, 2%, 0.5–1 mm, euhedral

Groundmass: plagioclase, 36%, 0.03–0.1 mm, skeletal needles; clinopyroxene, 35%, 0.03-0.1 mm, anhedral, feathery, opaques, 15%, 0.005–0.01 mm; mesostasis (devitrified glass), 7%

Vesicles: 5%, 0.1 mm, circular

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 4A, 27 cm	2.83	5.36	–	6

HOLE 470A, CORE 12, SECTION 1, 198.5–199.9 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPES – NANNOFOSSIL LIMESTONE, SEDIMENT CAVINGS

Macroscopic Descriptions

Basalt – medium dark gray, moderately altered and fractured. Aphyric and fine-grained; Pieces 2, 3, and 5 have glassy margins and grain size increase away from margins. Piece 9 has brownish altered margin.

Limestone – Pieces 3A–C are light colored nannofossil limestones that contain lower middle Miocene coccoliths (*Sphenolithus heteromorphus* zone), rare discoasters and sparse placoliths with variable secondary overgrowths. Limestone is the same age as sediment overlying basalt in Core 7. All limestone fragments have attached basalt pieces; glassy margin of basalt marks sharp contact with limestone.

Sediment Cavings – sediment at top of core (0–7 cm) is foraminiferal silty sand and contains upper Miocene coccoliths (*Amaurolithus primus* subzone). Cavings between 130–137 cm are sand carrying mixed upper middle Miocene radiolarians (*Cannartus petterssoni* zone), upper Miocene coccoliths (*Amaurolithus primus* subzone) and sparse middle Miocene coccoliths.

Thin Section Description

Aphyric Basalt – Piece 3D, 35–36 cm

Texture: aphyric, hypocrystalline to subvariolitic

Groundmass: plagioclase, 15%, 0.01–0.4 mm, skeletal needles; clinopyroxene, 10%, 0.01–0.1 mm, skeletal, feathery; opaques, 5%; mesostasis, 70%

Vesicles: 5%, 0.5–0.3 mm, irregular to circular

Alteration: calcite and zeolites fill vesicles; clay occurs in altered mesostasis

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 6B, 74 cm	2.79	4.86	–	7

HOLE 470A, CORE 13, SECTION 1, 207.5–208.5 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – medium dark gray, aphyric to porphyritic and moderately altered. Piece 5 is glass; Pieces 1 and 4 are medium-grained with subophitic to intersertal texture. Rest of pieces are fine-grained.

Thin Section Descriptions

Aphyric Basalt – Piece 4, 30–32 cm

Texture: subophitic to intersertal

Groundmass: plagioclase, 41%, 0.1–1 mm, prismatic laths; clinopyroxene, 40%, 0.1–2 mm, anhedral, $2V = 35^{\circ}–45^{\circ}$; olivine (partly altered), 3%, 0.05–0.1 mm, anhedral, equant; opaques, 8%, 0.01–0.1 mm, acicular; mesostasis, 8%

Phyric Plagioclase Basalt – Piece 8, 67–69 cm

Texture: porphyritic with intergranular to intersertal groundmass

Phenocrysts: plagioclase, 3%, 0.2–0.4 mm, euhedral

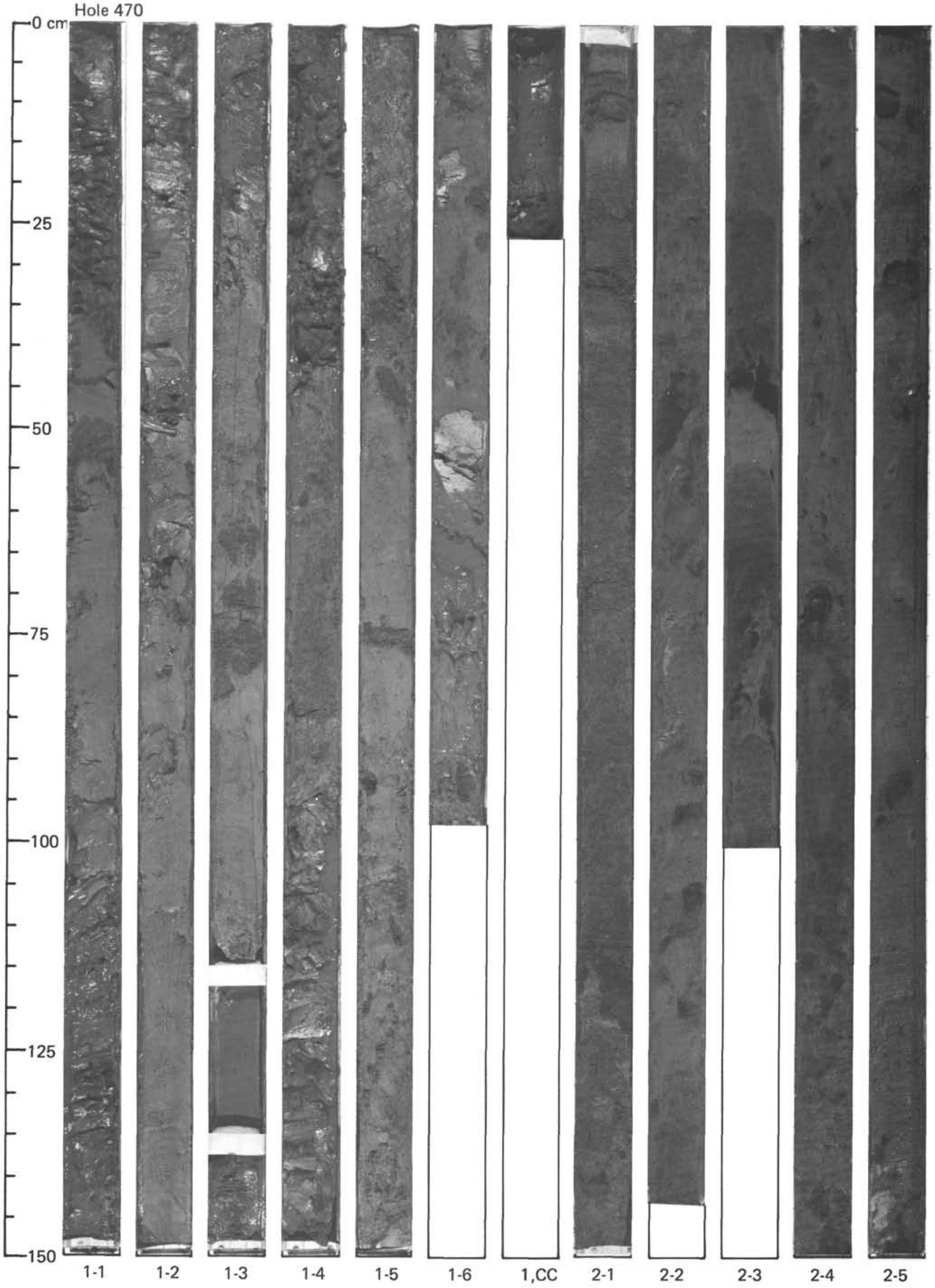
Groundmass: plagioclase, 37%, 0.01–0.1 mm, slender prismatic laths; clinopyroxene, 40%; 0.01–0.1 mm, anhedral, equant; opaques, 10%, 0.01–0.03 mm; mesostasis, 7%

Vesicles: 3%, 0.2–0.3 mm, circular

Alteration: brownish green clay fills vesicles and occurs in mesostasis

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 4, 30 cm	2.91	5.42	–	4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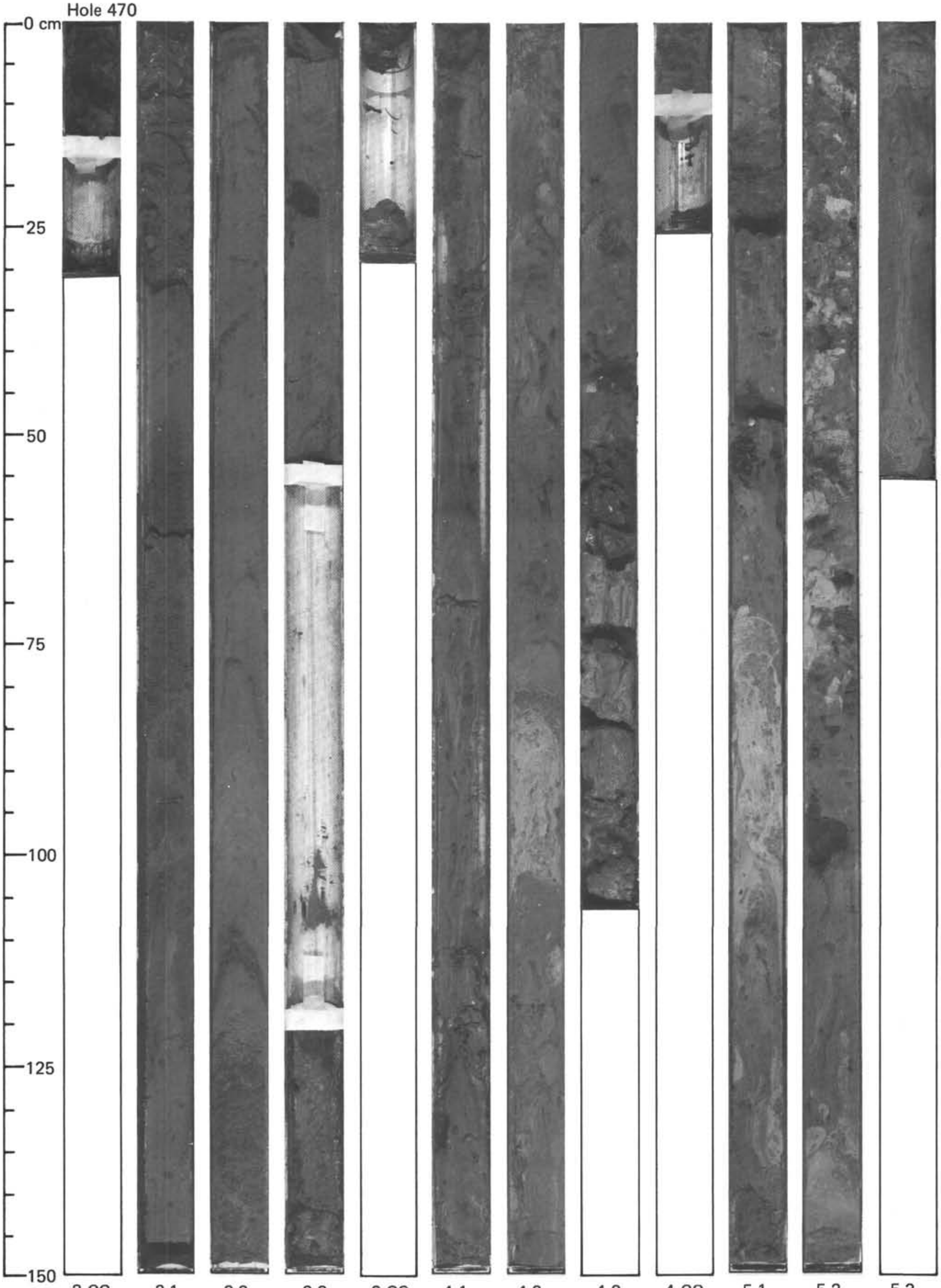
2-4
2-5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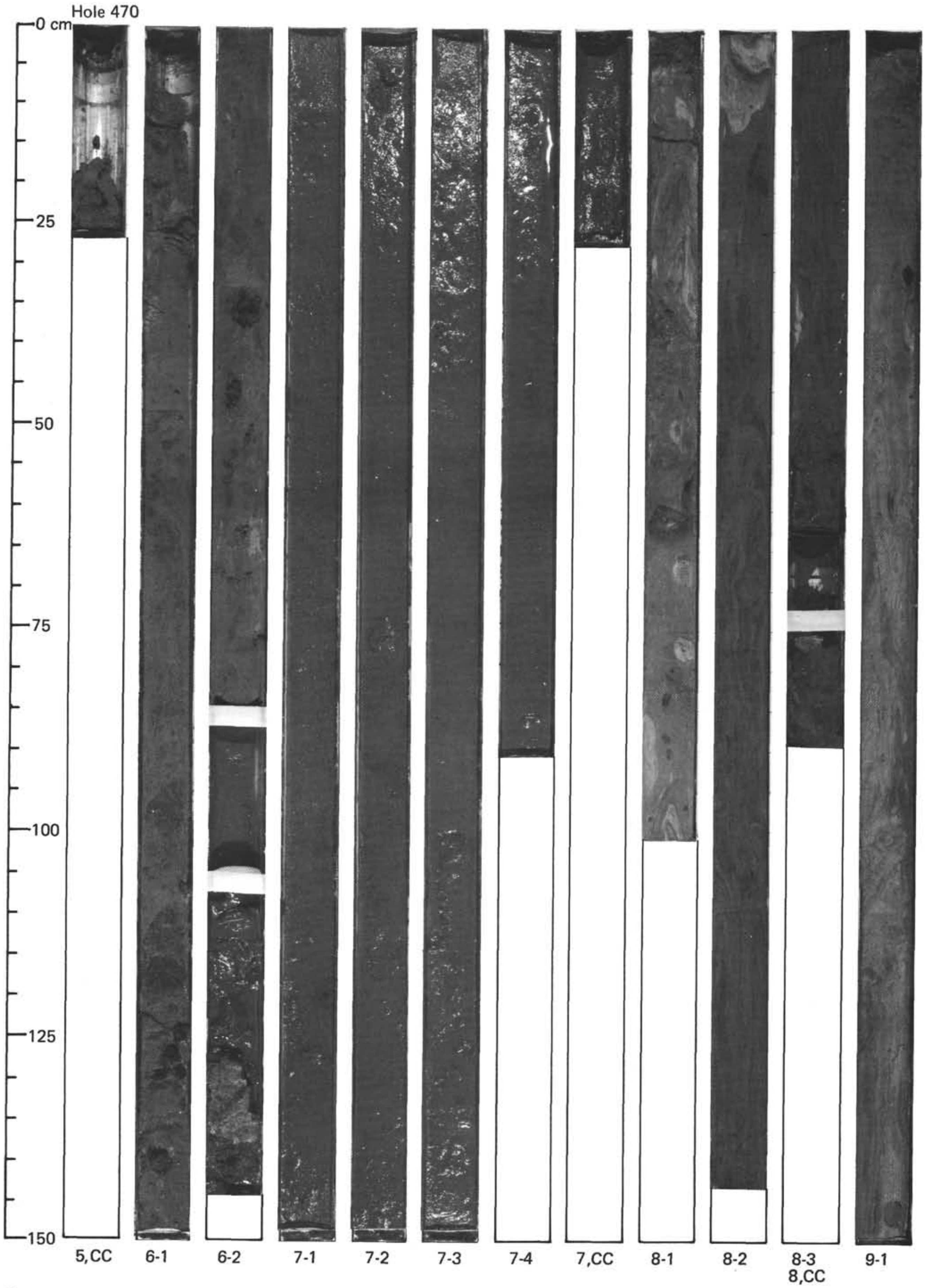
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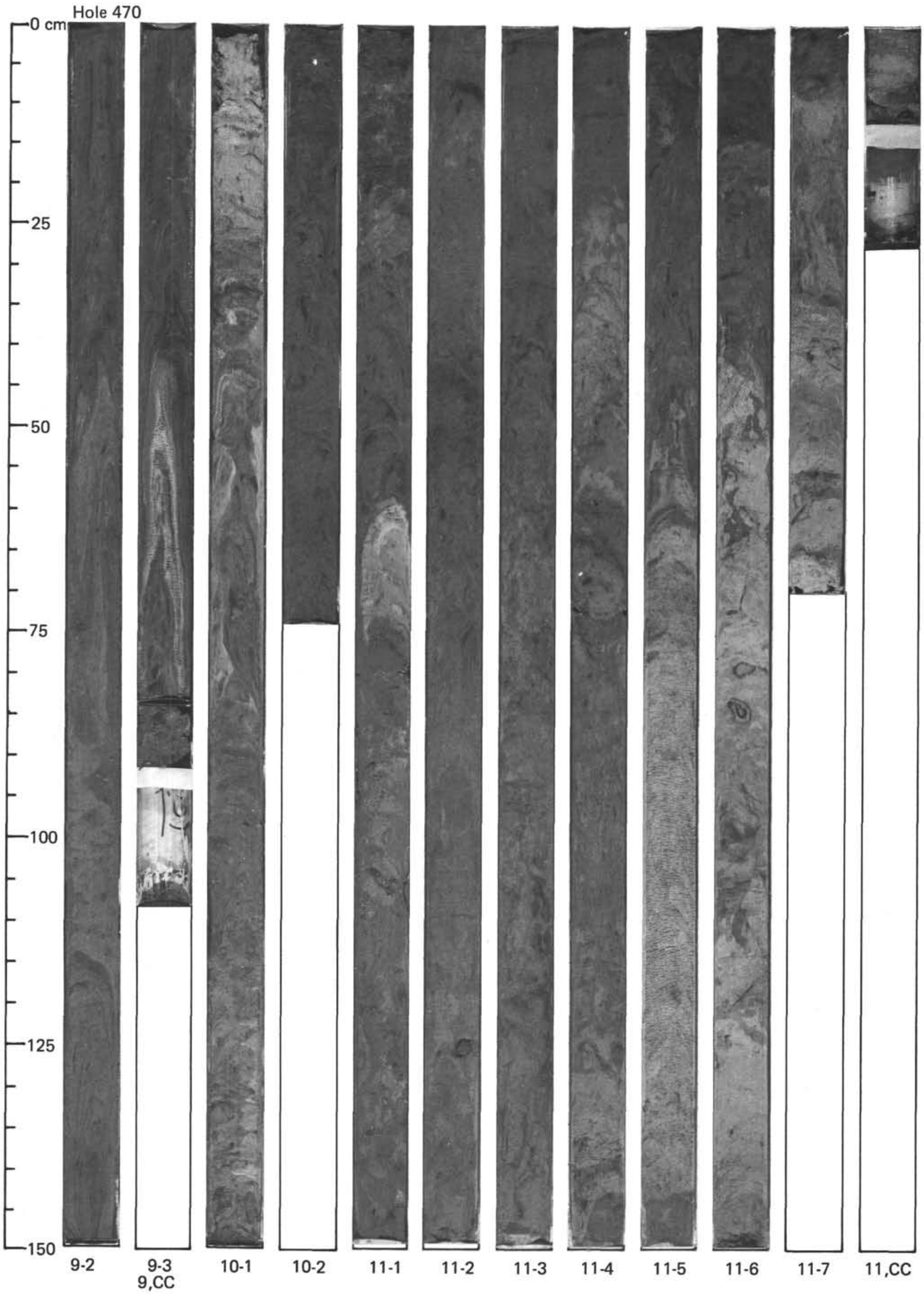
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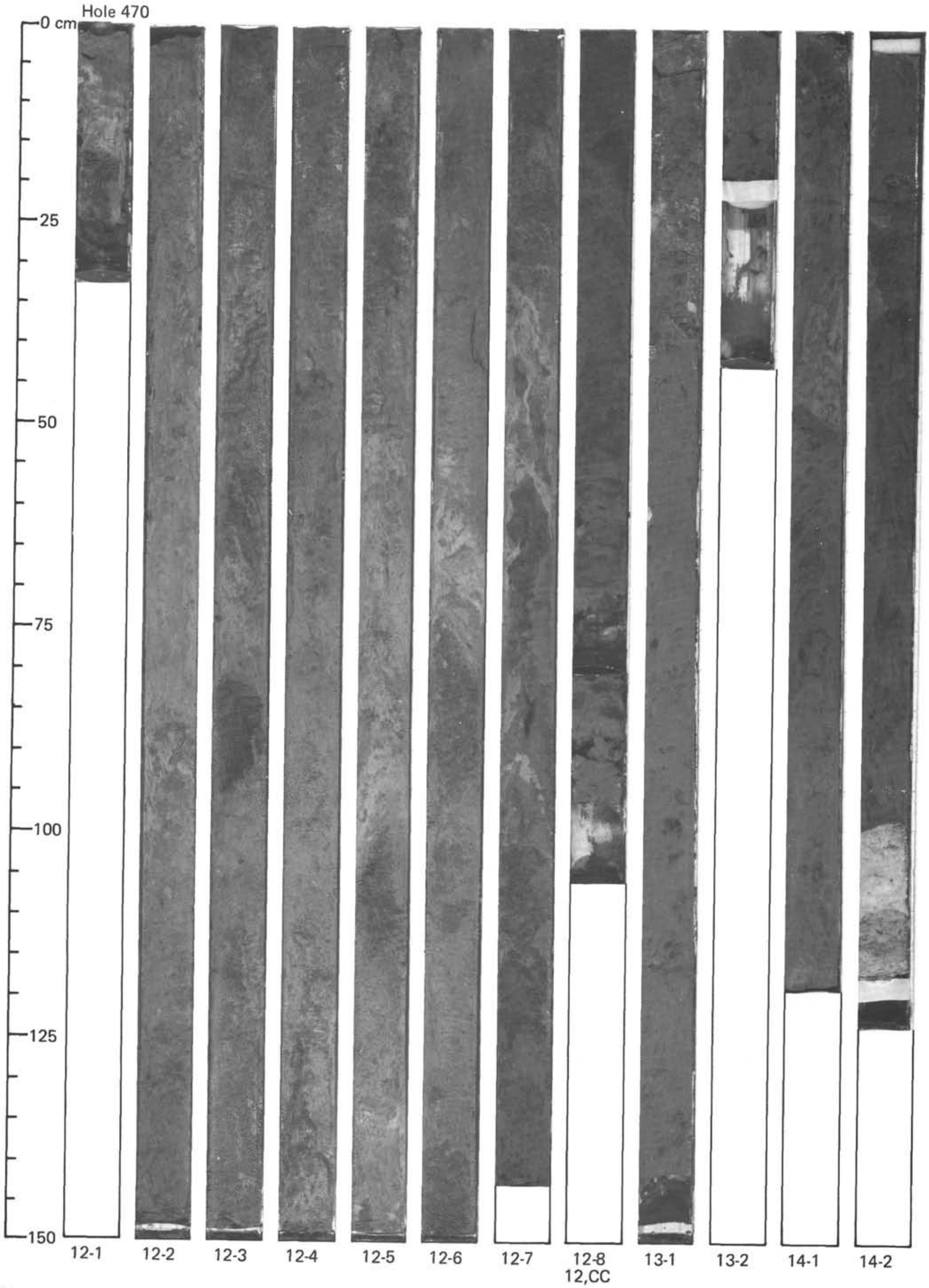
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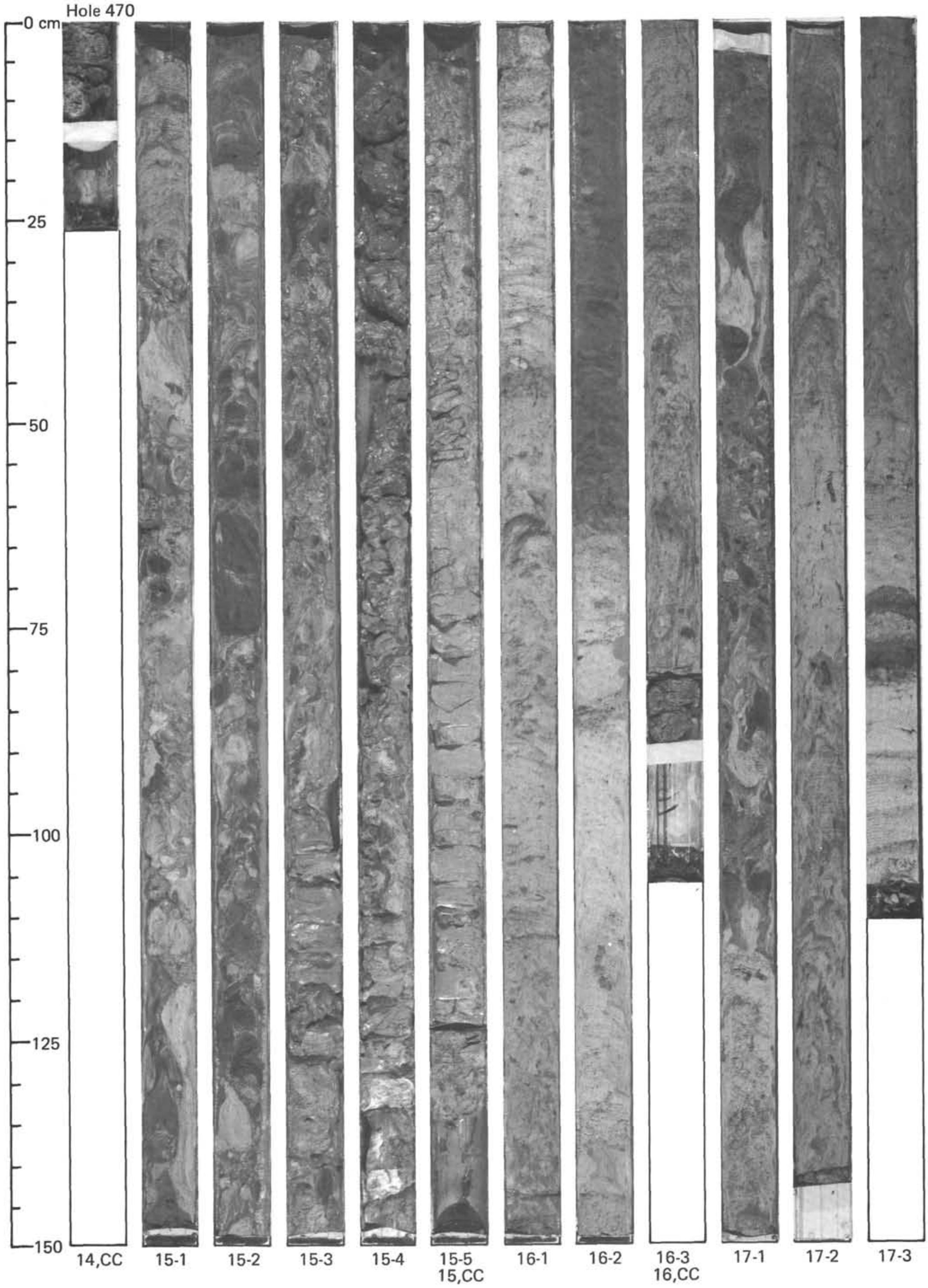
14-2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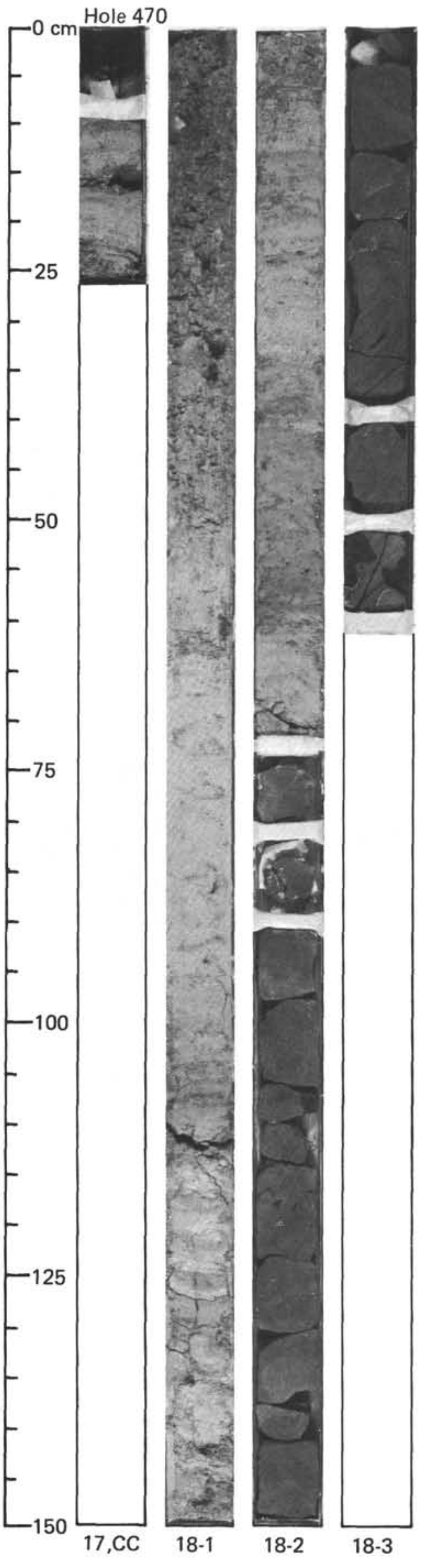
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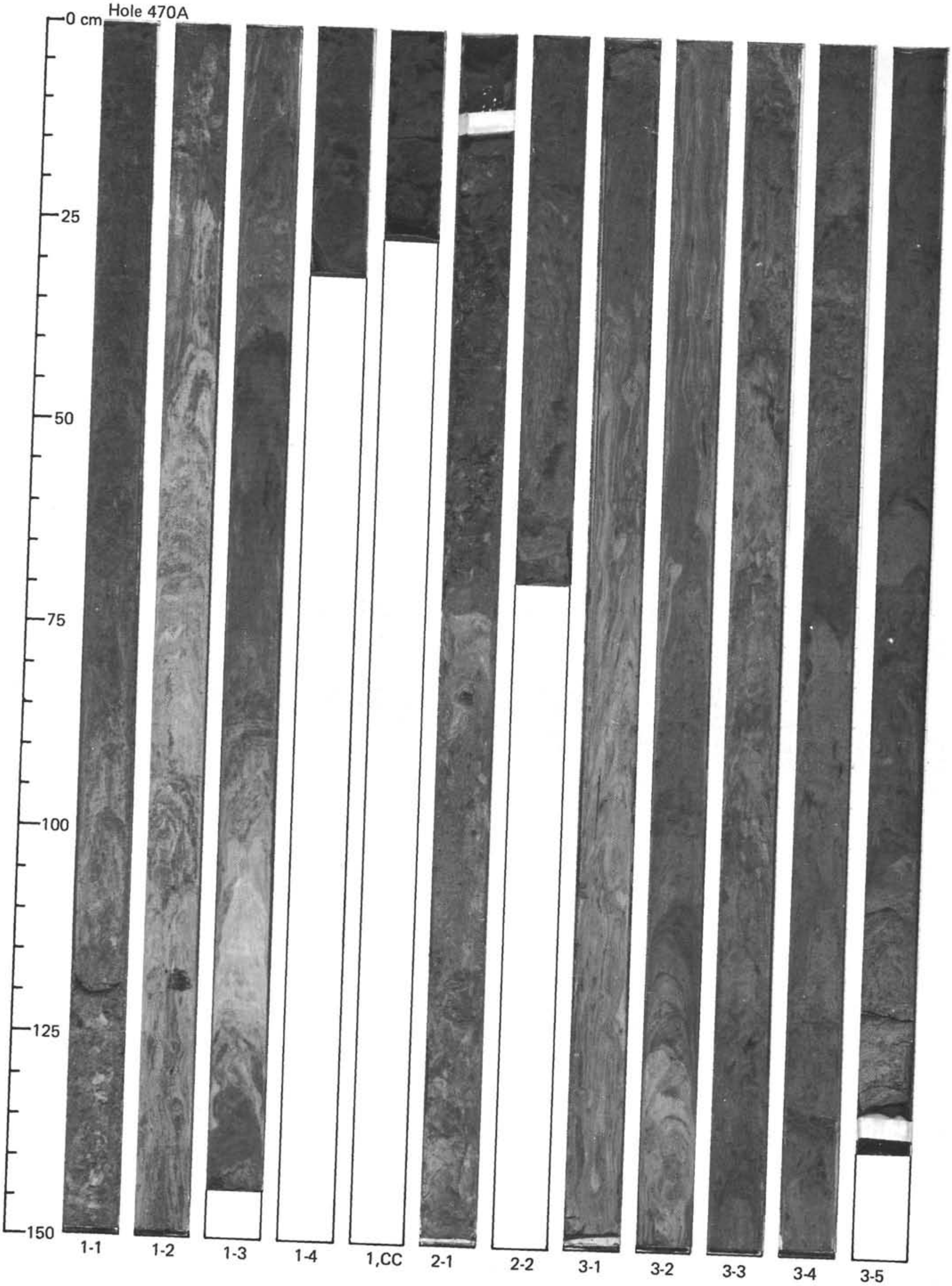
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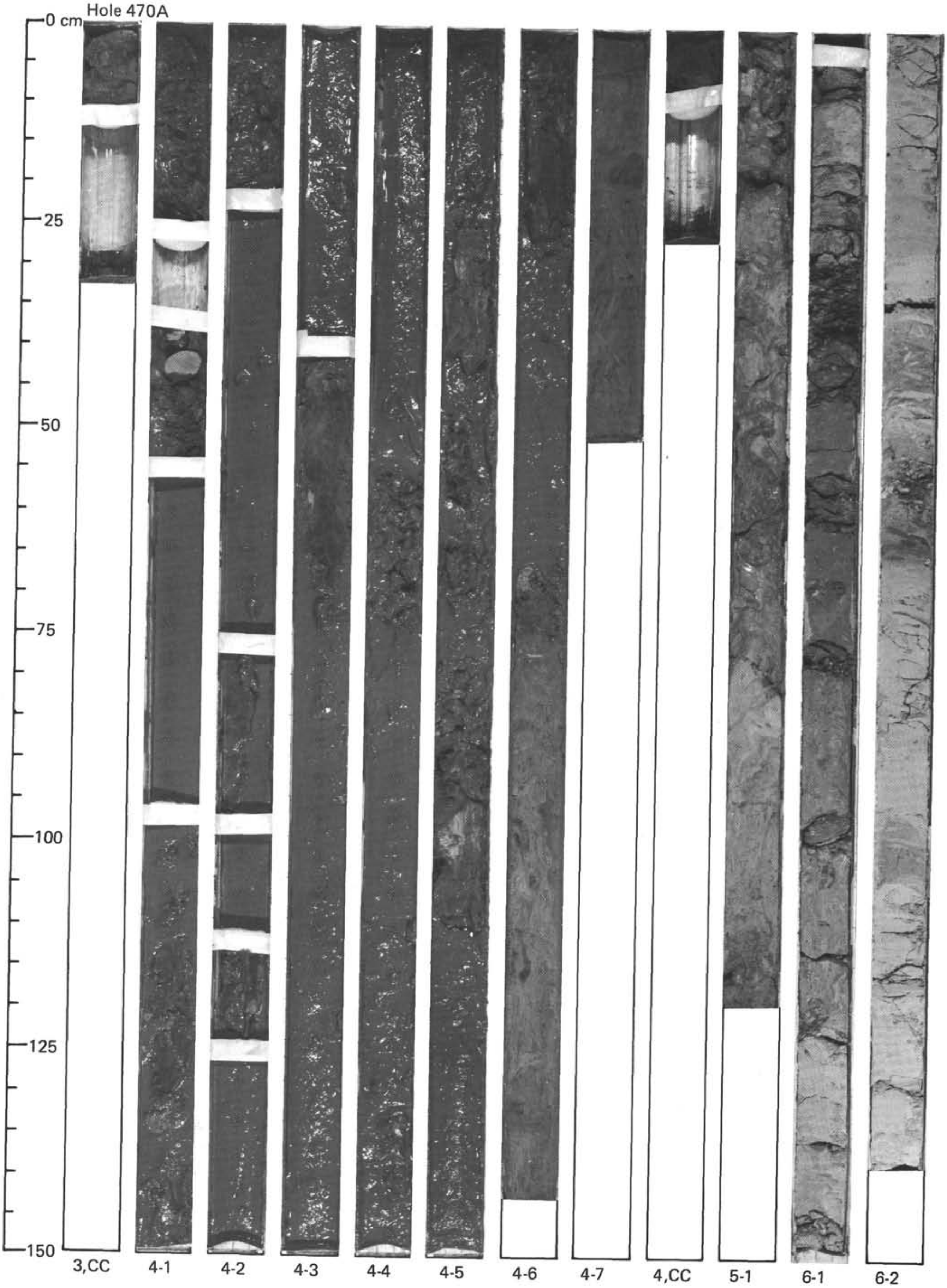

Hole 470A
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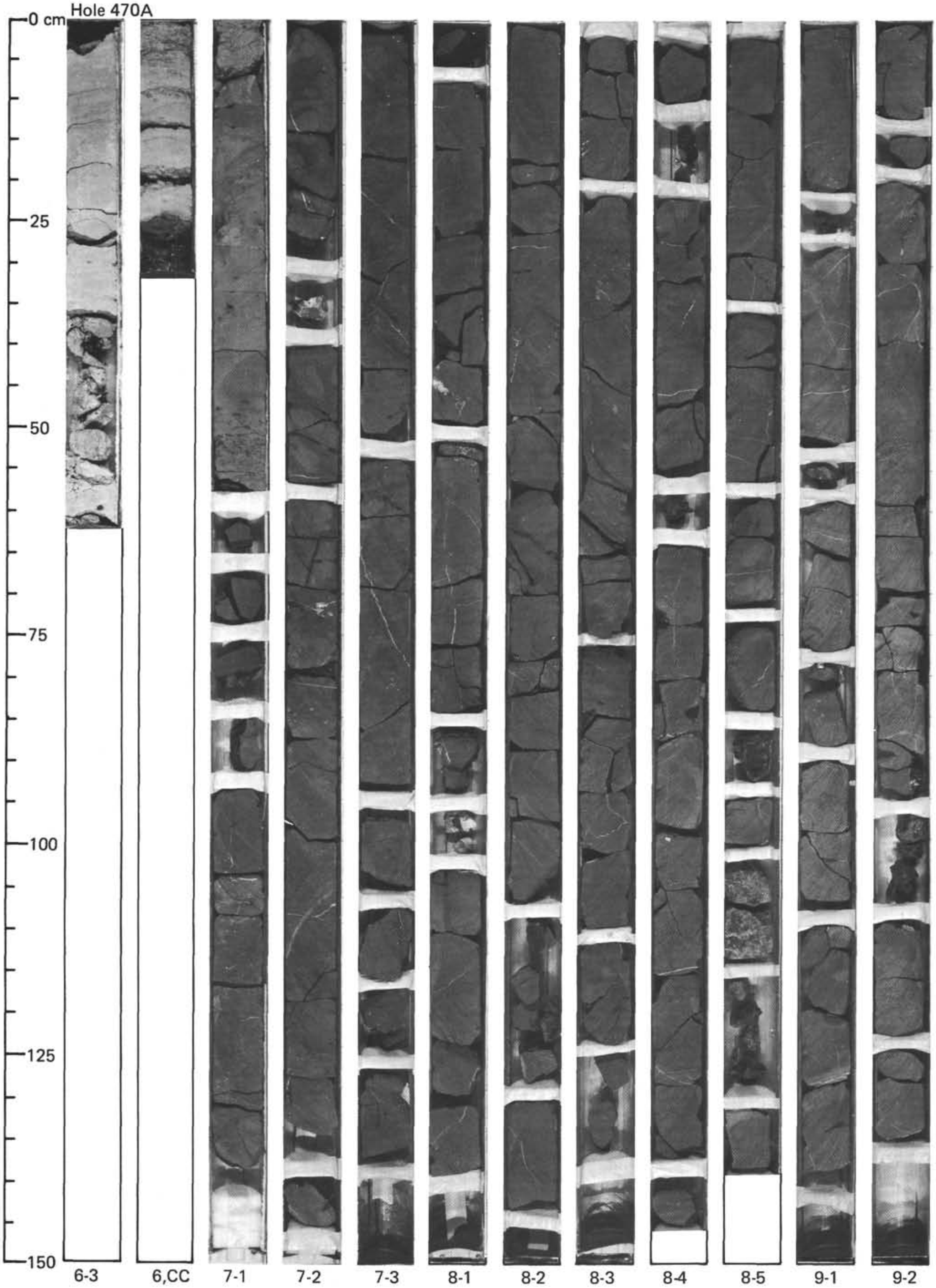
5-1
6-1
6-2


0 cm
Hole 470A
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150
6-3
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8-1
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8-3
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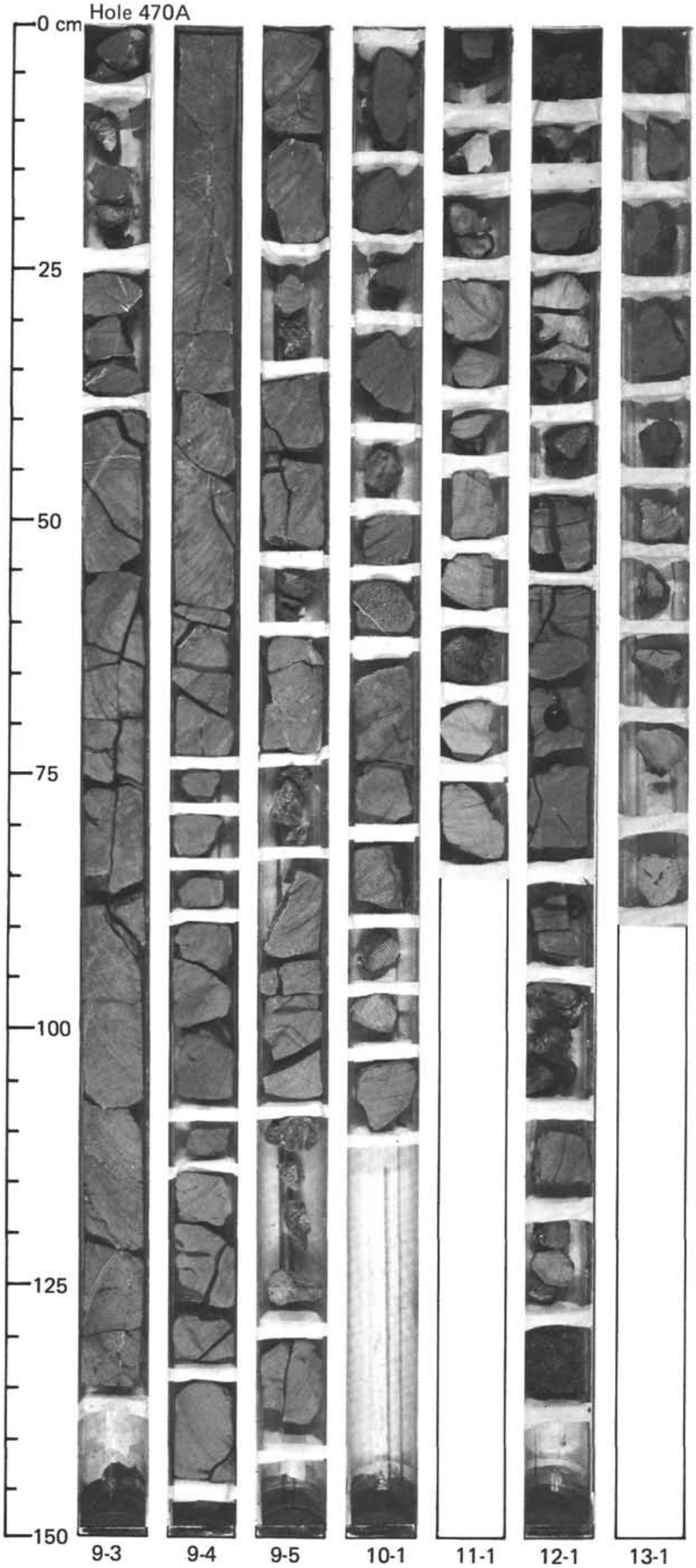
8-5
9-1
9-2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